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† In marine separate.

CORRECTION

REVIEW, March, 1925:

Page 101, first column, third line below the legend to Fig. 3, "4,000 meters" should be "4,000 feet."

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY — Assistant Editor, BURTON M. VARNEY

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W. B. No. 867

APRIL, 1925

CLOSED JUNE 3, 1925
ISSUED JUNE, 1925

THE TORNADOES OF MARCH 18, 1925 [1]

By ALFRED J. HENRY

The destructive tornado that swept eastward over parts of Missouri, Illinois, and Indiana, together with those of shorter path in Kentucky and Tennessee, on March 18, 1925, created a new record of destruction both of human life and property from these much-dreaded storms. Seven separate and distinct tornadoes were observed on the date mentioned, the most destructive of which was the one starting near Annapolis, Mo., which moved in an almost straight line to the Mississippi River, crossing that stream into Jackson County, Ill. It laid waste a number of towns and villages as it crossed Illinois, continuing its devastating course into Indiana and finally disappearing 3 miles southwest of Petersburg, Pike County, Ind.

Two Weather Bureau officials, William E. Barron, of the Cairo station, and Clarence J. Root, of the Springfield station, were at once directed to survey the path of the storm.

Grateful acknowledgment is here made for the matter I have drawn from the report of these two officials. Information as to the remaining tornadoes was drawn largely from the printed issues of "Climatological Data" for the States in which the storms occurred.

THE CYCLONIC STORM THAT GAVE RISE TO THE TORNADOES

The previous history of the cyclonic storm with which the tornadoes were associated is not illuminating; evidently the storm was an offshoot from a cyclone which occupied the northeast Pacific from March 13 to 18. This offshoot was first recognized on the p. m. chart of the 16th as a depression centered over western Montana. At that time and during the next 24 hours, this depression gave no evidence of anything out of the ordinary; on the morning of the 18th it was centered in northwestern Arkansas, as shown in Figure 1 (A). At this time, 7 a. m. 90th meridian time, the center of lowest pressure was shown by the isobars of 29.8 and 29.7 inches, respectively, both isobars being within a trough of low pressure that extended in a NE.-SW. direction.

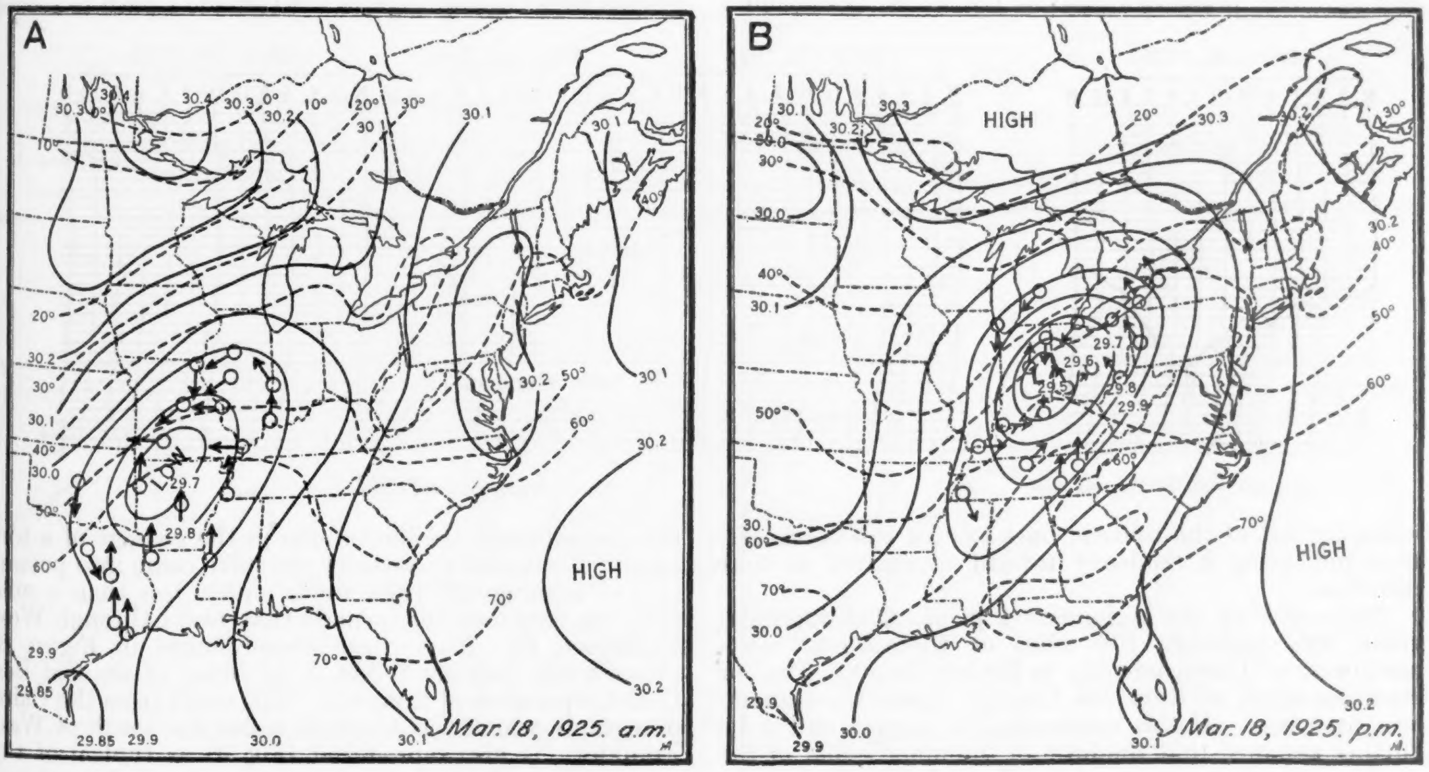


FIG. 1.—Weather maps for 8 a. m. and 8 p. m., March 18, 1925

Movement of the cyclone.—During the daylight hours of the 18th the center of lowest pressure was displaced northeastward a distance of about 500 miles to southeastern Indiana, as shown in Figure 1 (B), or at the rate of about 40 miles per hour.

For the purpose of better relating the progression of the center of lowest pressure with that of the formation and progression of the tornadoes, weather charts covering the lower Ohio Valley for the hours 1, 2, 3, and 4 p. m., central meridian time, were constructed. The charts for 1 and 4 p. m. have been reproduced in the lithograph charts in Figure 2 (A and B).

[1] Condensed from reports by the following field officials: J. H. Armington, William E. Barron, James L. Kendall, Roscoe Nunn, George Reeder, Clarence J. Root, and Geo. B. Wurtz, with discussion by the editor on the meteorological aspect of the phenomenon. Details of loss of life and damage to property were included in this REVIEW for March, 1925, and may also be found in the publication "Climatological Data" for Missouri, Illinois, Indiana, Kentucky, and Tennessee for the same month.—ED.

On the A chart the tracks of the tornadoes are shown by a heavy line. The times of beginning and ending of each tornado are also shown, and the times of beginning have been used as a basis of classification into (a), (b), (c) storms, etc.

As before intimated, the pressure formation was not characterized by circular isobars but consisted of a rather restricted region of low pressure within a trough of low pressure whose longer axis extended in a NE.-SW. direction. The apparently rapid movement of the central low pressure is well understood by forecasters since the southern center of low pressure in a trough often moves with great rapidity toward the opposite end of the trough and thus the center of the formation as a whole is sometimes carelessly considered as having a very rapid rate of translation.

The intermediate charts.—The charts for 1 to 4 p. m., 90th meridian time, show rather conclusively that not only did the center of low pressure move rapidly northeastward but also that in so doing the formation as a whole passed from that of a trough to that of oval-shaped isobars oriented in the same general direction as those of the earlier formation.

The 1 p. m. chart (fig. 2 (A)) shows the lowest pressure at Cairo with pressure almost as low at St. Louis and a being about 200 miles northeast of Cairo and registering a greater pressure fall, seems to indicate that the development of the storm was in some way conditioned upon the great temperature contrast on the northern border of the mass of warm southerly winds at the time flowing over southern Illinois and Indiana, which may have had more of a westerly component aloft than at the surface.

At 3 p. m. the center of low pressure had assumed the form of a long narrow oval stretching from Cairo with pressure of 29.56 inches to Terre Haute, Ind., with pressure 29.59 inches, and the whole disturbance had now largely passed from the "trough" form to that of an oval, the latter being oriented in a NE.-SW. direction.

The 4 p. m. chart is reproduced as (B) in Figure 2. Lowest pressure is now at Terre Haute, Ind., 29.55 inches.

THE BAROGRAPH TRACES

The barograph traces in the path of the cyclonic storm we have been considering show not only its progression from hour to hour, but also that a disturbed condition of the atmosphere, as indicated by short irregular fluctuations in the pressure, prevailed during the early morning hours of the 18th. None of the Weather Bureau barographs were close enough to the tornado's path to record

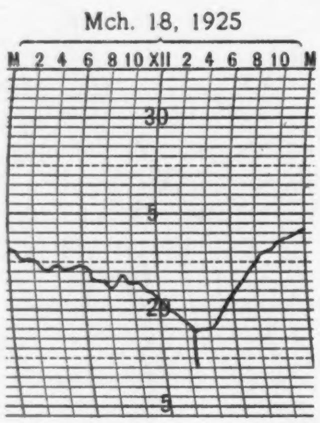


FIG. 3.—Barograph trace, Old Ben coal mine

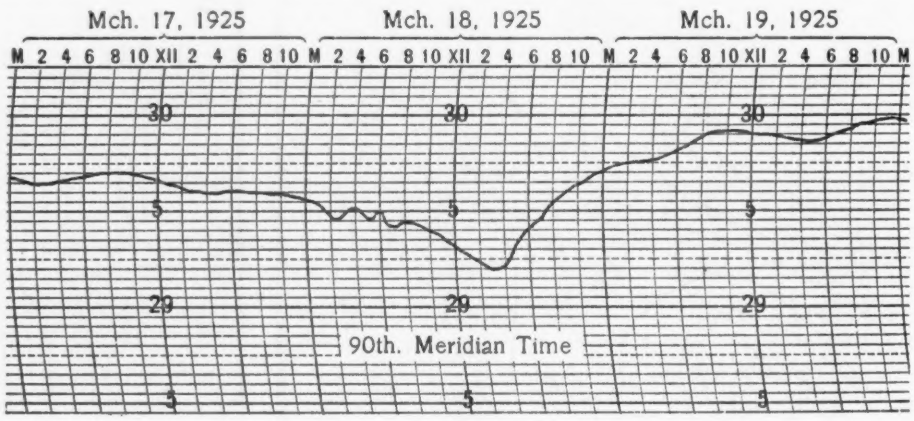


FIG. 4.—Barograph trace, Cairo

widening out of the isobaric lines toward the northeast, thus indicating a tendency toward movement in that direction.

The center of the cyclone at 1 p. m., 90th meridian time, was probably 100 miles or thereabouts west-southwest of Cairo, possibly in Ripley County, Mo., or 40 miles south of Reynolds County, where the tornado was first seen. If this assumption be correct and it be further assumed that the form of the inner isobar of the cyclone was that of a north-south oval, then it may be said that the tornado probably developed in the northern left front of the cyclone—the northwest quadrant. The left front is a more probable place of origin than the right front since the tornado moved with greater speed than the cyclone, and, as we shall see later, the paths of the two phenomena over Illinois and Indiana were nearly concurrent in point of time but not parallel in direction. The tornado moved in a direction 21° north of east while the center of the cyclone followed a slightly curved path over Missouri and Illinois, concave to the north. (See Path No. VIII, chart 2, March, 1925, REVIEW.)

At 2 p. m. pressure at Cairo had fallen to 29.60 inches and at Terre Haute, Ind., to 29.62 inches; whereas at Evansville, Ind., about 112 miles due northeast of Cairo, pressure had fallen to 29.65 inches only. Terre Haute the characteristic oscillation due to the passage of a tornado. Fortunately, however, we have come into possession of a baragroph trace made within less than a mile from the center of the tornado that swept through West Frankfort, Ill. This trace is reproduced in Figure 3, through the courtesy of Mr. J. E. Jones, of the Old Ben Coal Corporation of that city. The curve from the Cairo barograph, which was about 65 miles due south of West Frankfort, is also reproduced (Fig. 4) as typical of the curves from other instruments near the tornado path.

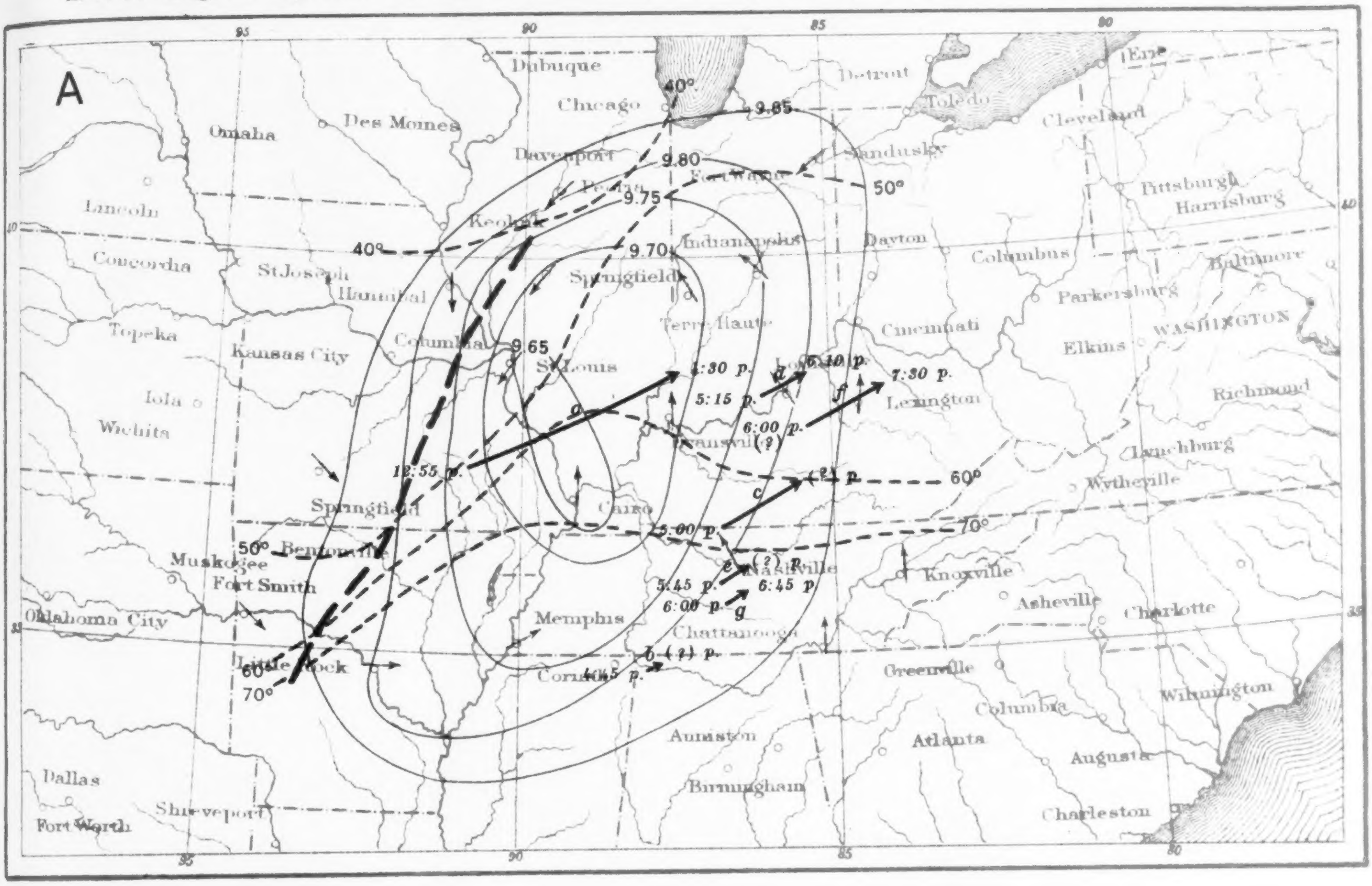
THE TORNADO PATHS WITH REFERENCE TO THE CENTER OF THE CYCLONE

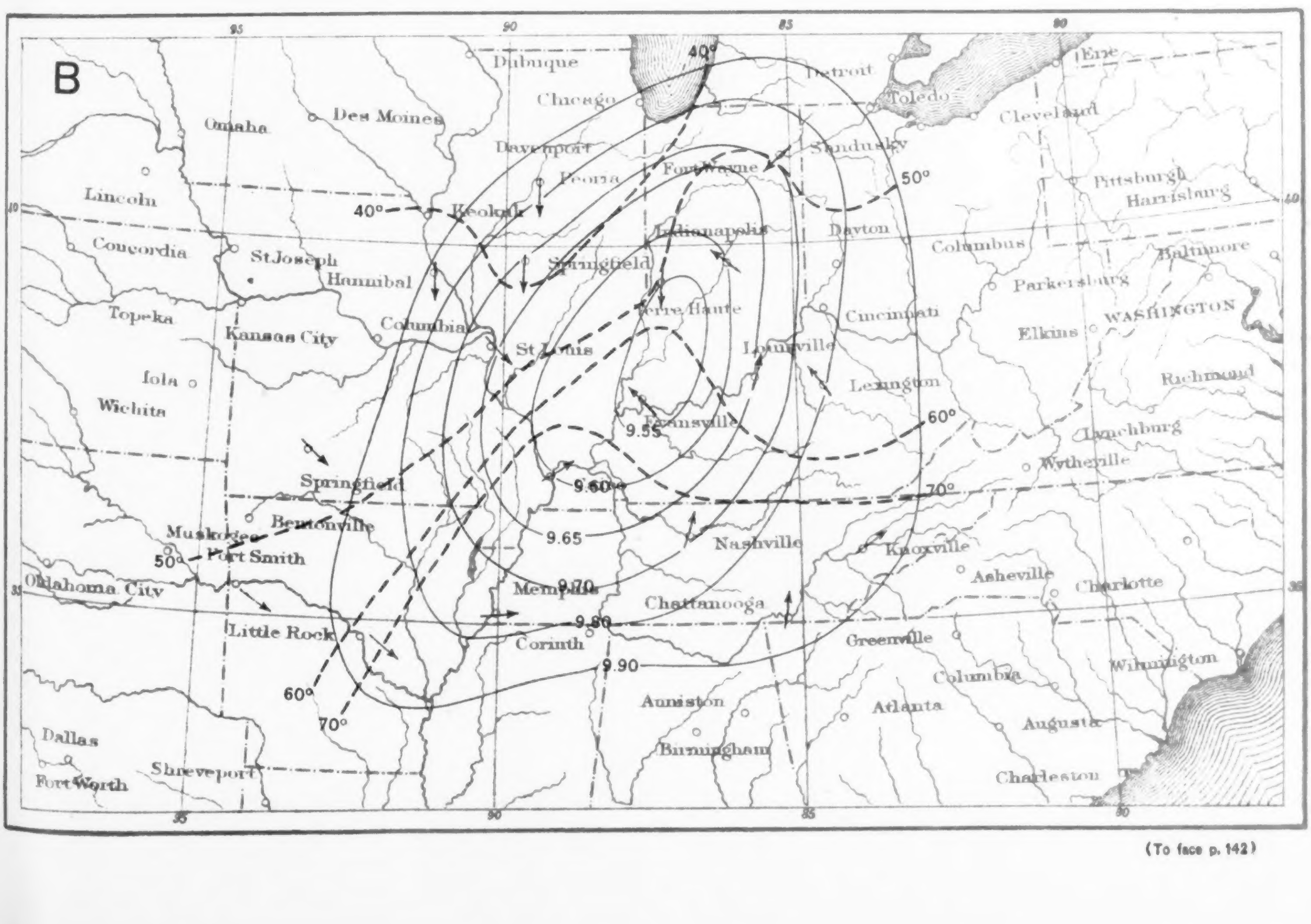
Investigations of the last 40-odd years have shown that tornadic storms mostly occur in the southeast quadrant of a general cyclonic disturbance and at a distance that may range from 200 to 600 miles from the cyclone center.

The editor does not recall having seen an authoritative record of the occurrence of a tornado in or very close to the center of a general cyclone up to the present case.

It has been suggested that the (a) tornado as depicted on Figure 2 (Chart A) had its origin in the left half and well toward the front of the cyclone shown on that chart.

A. J. H. **Fig. 2. Cyclone Center at 1 and 4 p. m., respectively, Central Time, March 18, 1925**





(To face p. 142)

The movement of the tornado across southern Illinois is definitely fixed by the time at which the train despatchers' wires went out of commission. The evidence of the barograph traces for West Frankfort and Cairo (figs. 3 and 4), and also that of the time of the tornado's crossing into Indiana, and the Terre Haute barograph, go to show that the two phenomena—the tornado and the cyclonic storm—moved very nearly concurrently but not parallel, the tornado in the later portion of its path being on the south or the side on which warm southerly air prevailed. The remaining tornadoes developed later in the afternoon and much more distant from the cyclone center, and in this they conformed to the experience of many years' study of that phase of the phenomenon.

Mention may also be made of the fact that the form of the isobars on March 18 greatly resembled that on February 19, 1884, on which day 44 tornadoes were observed in the east Gulf States, the Carolinas, and Georgia. On March 18, as on the date above mentioned, the time of occurrence of the tornadoes was later and later in the day and farther and farther to the eastward as the afternoon hours were passed.

FREE AIR METEOROLOGICAL OBSERVATIONS AND DEVELOPMENT OF TORNADOES ON MARCH 18, 1925

Stations south of the cyclone center.—The records from two points are available, viz, Broken Arrow, Okla., and Groesbeck, Tex. The geographical coordinates of the four kite stations are given in the table below:

Station	W. longitude		N. latitude		Elevation
	°	′	°	′	Feet
Broken Arrow	95	49	36	02	764
Groesbeck	96	28	31	30	463
Drexel	96	16	41	20	1,299
Royal Center	86	29	40	53	738

March 17.—Southerly winds turning clockwise to W.-SW. at 3,587 m. (11,768 ft.) prevailed at Broken Arrow; at Groesbeck the clockwise turning was also in evidence, but after reaching W.-SW. the winds backed to SW. and increased in speed to 19.0 m. p. s. at 3,780 m. (12,401 ft.)—the top of the flight. The maximum wind speed at Broken Arrow was 14.7 m. p. s. at 1,000 m., and but 12.8 m. p. s. at the highest point reached.

The temperatures of the air column above both stations were alike in that the lapse rate up to the 2 km. level was small and at both stations there was a more or less pronounced inversion of temperature, at approximately 1,000 m. at Broken Arrow and 1,500 m. at Groesbeck. Up to these levels (3,000 to 4,000 ft.) the air strata were in stable equilibrium.

March 18.—As the center of the cyclonic storm passed to the eastward of the meridian of these stations the winds very naturally went to northerly and the temperature at Broken Arrow fell several degrees in all levels. Groesbeck, more distant from the center of the cyclone, also experienced northerly winds, but only small changes to lower temperature, so that instead of an inverted temperature layer in the air column there was a small lapse rate from the surface to 3,000 m. (9,842 ft.), also a condition of stable equilibrium.

Stations north of the cyclone center. Drexel, March 17.—On this date S.-SE. surface winds turned clockwise to SW. at 1,780 m. (5,840 ft.)—the top of the flight. The temperature at that level was 3.6° F. higher than at the surface and, as at the southern stations, there was a rather pronounced temperature inversion with its maximum at the 1 km. level.

On the following date the winds were NNW. at the surface, backing to NE. at the top of the flight, 2,765 m. (9,071 ft.), and there was a fall in temperature ranging from 5 to 15° F. in the several levels. All of these changes are in accord with what might be expected, owing to the changed geographic position of the cyclone center with respect to Drexel.

Royal Center, March 17.—This station was under the influence of the southeastern anticyclone; accordingly winds were SSW. at the surface, turning to SW. and WSW. at the highest level reached, 2,848 m. (9,344 ft.). On the 18th as the cyclone center approached from the SW., the NNE. surface winds became E. at the top of the flight, 1,815 m. (5,954 ft.). The lapse rate on the 17th was about half the adiabatic, and on the 18th, while it had increased somewhat, was yet not more than half of the adiabatic.

The chief facts brought out are therefore: (1) The existence of a rather strong southerly current in front of the cyclone on the 17th which apparently extended from the Gulf of Mexico to the Great Lakes, possibly to the Canadian border; (2) the current was warm in the lower levels and cold above 3 km., with a rather small lapse rate between the surface and that level, therefore stable; (3) indications drawn from the barograph curves point to an instability in the atmosphere in the early morning hours of the 18th and that this instability progressed from west to east concurrently with the advance of the cyclone center. Finally, the free-air records give no direct indication of the forces which institute and maintain the tornado vortex although the presence of a warm layer of air at the 1-km. level, if sufficiently warm, of which we have no knowledge, may have conspired with other conditions to pierce the cold upper ceiling by vertical convection and thus induce a vortex which later will reach the earth's surface. In this instance there is no warrant for assuming that such conditions obtained. It must also be reluctantly admitted that there is little hope that the actual conditions that initiate a tornado vortex will ever be experimentally observed.

GENERAL REMARKS

The (a) tornado.—Messrs. Barron and Root, by using an automobile, were able to cover the track of the (a) tornado in Illinois and Indiana in seven days. From its inception in Reynolds County, Mo., the tornado pursued a remarkably straight path through Iron, Madison, Bollinger, and Perry Counties, of that State, and across Illinois, passing through the counties of Jackson, Williamson, Franklin, Hamilton, and White. It continued its course with slight deviation through the counties of Posey and Gibson in Indiana, and terminated as a destructive tornado 3 miles southwest of Petersburg, Pike County, Ind.

The total length was 219 miles with an average width of less than 1 mile. Its speed in Missouri was 57 m. p. h.; Illinois, 59; and Indiana, 68.

In western Illinois very few observers reported the presence of a funnel-shaped cloud; farther east, however, some thought they saw such a cloud, especially those who were on the outside of the storm's path. These witnesses were not very definite as to what they saw but all agreed that two clouds came together. This appearance is perhaps the most common testimony of pesons observing tornadic storms. It has been repeatedly given since investigations on this type of storm were begun some 40-odd years ago.

There is no doubt but that clouds are seen rushing toward a common point, viz, the vortex of the tornado. As explained by Professor Davis many years ago, it is not the rushing together of two clouds that creates the tornadic whirl but rather this cloud motion is the visible result of the whirl already in existence.

Root suggests that the absence of a funnel-shaped pendant cloud may be due to the fact that the main cloud was so close to the earth that there was no room left for the formation of the usual funnel-shaped cloud. The writer pointed out many years ago [2] that the character of the pendant funnel-shaped cloud varies with geographic position and the average hygrometric state of the air.

Thunder was heard quite generally a few minutes in advance of the tornado; rain and hail fell at various places. Hail was moderately heavy at Gorham, West Frankfort, and Carmi, Ill., and east of Princeton irregular-shaped chunks of ice as large as goose eggs were reported.

The usual roaring sound as of several freight trains was heard.

Loss of life and property.—For convenience the statistics of loss of life and injury to persons and property loss published in the March REVIEW are here repeated, with slight revision based on later estimates, in Table 1.

TABLE 1.—*Deaths, injuries, and property losses in the seven tornadoes of March 18, 1925*

Tornado	Deaths	Persons injured	Property losses
a	742	2,771	$16,532,000
b	1	12	15,000
c	38	98	200,000
d	6	101	225,000
e	1	9	30,000
f	2	35	850,000
g	2	7	20,000
Totals	792	3,033	17,872,000

Root and Barron say with respect to further details of the (a) tornado:

From inquiries made among the country people it would seem that they had about five minutes' warning after first noting the cloud. Asked as to the length of time in which the destruction took place, opinions varied, but most persons thought about two minutes. If the whirl was round, the path of the storm 1 mile or less in width, and the velocity of translation about a mile a minute, then the tornado would pass a given point in one minute or less.

There was much sameness throughout, the degree of property damage simply depending on what was in the track. The tornado advanced across the country with undiminished intensity and none of the lifting and skipping commonly attributed to this type of disturbance.[3]

Topography seemed to have little effect on the action of the storm. All farm properties were damaged or destroyed, and in most cases there was complete demolition. Livestock were killed, fences blown down, automobiles and machinery damaged, grain and supplies scattered about, and in many cases entire orchards were uprooted. In some cases residences were carried from the foundations, with scarcely a board left in the immediate vicinity. The country was strewn with débris. Freight cars were turned over. The term "utter confusion" nicely illustrates conditions in the tornado zone. * * * The tornado did not cut a swath through the timber. In numerous places there was severe damage, many trees being broken off or uprooted. In other areas there was little destruction. Trees were down here and there in all parts of the storm's track.

It may be wondered why the number of casualties was so great. In the first place, the path was of great length and was wider than usual, thus embracing an unusually large area. * * * There are relatively few basements in this region and surprisingly few storm caves. Where could the people take refuge? Many did not realize the danger present, thinking it merely a severe thunderstorm. Some entered the houses to take shelter from the rain. Notwithstanding the great number killed or injured, there were many remarkable and almost unbelievable escapes.

The (b) tornado.—This was doubtless a true tornado, but of relatively little intensity, short path, and short duration. It originated in Colbert County, Ala., about 6 miles north of Russellville.

The (c), (e), and (g) tornadoes.—This grouping is made for convenience of description, since all of the storms occurred in west-central Tennessee. The (c) storm was first observed 8 miles north of Gallatin, Sumner County, Tenn., at about 5 p. m., when the cyclone center was in extreme western Indiana and about 200 miles distant. This tornado cut a swath of from 200 to 400 yards in width and 15 miles long through the northern part of Sumner County, continuing about 50 miles farther into Adair County, Ky. The intensity of the storm decreased somewhat in the latter part of its course.

The (e) storm began 45 minutes later than the (c) storm and 50 miles almost due south of it, moving in a northeasterly direction. Its path was from 100 to 400 yards wide and about 20 miles long and it was not so severe as the one immediately preceding.

The (g) storm had a path 100 to 200 yards wide and moved in a northeasterly direction, paralleling that of the (e) storm. It was not a storm of great intensity, and it would seem that in the group of three storms here considered their intensity diminished in proportion to their distance from the cyclone center.

The (d) and (f) tornadoes.—The (d) storm was first seen about 75 miles southeast of the point where the (a) tornado disappeared, and the (f) tornado was first observed about 75 miles due south of where the (d) tornado disappeared. The path of the former was 40 miles long and that of the latter about 60 miles.

The occurrence of these tornadoes, each one successively farther and farther to the south and closely related in point of time, suggests an analogy between the origin of secondary cyclones and tornadoes.

It is a matter of common knowledge that when a cyclonic system entering the continent from the Pacific can not progress eastward along the northern boundary by reason of the presence of untoward atmospheric conditions a secondary cyclone will almost always develop to the southward of the primary. Similarly, it is conceivable that the (a) tornado of this series gradually found itself in atmospheric surroundings which made its further endurance impossible; hence the whirl lost contact with the earth and soon disappeared. Farther south, where the atmospheric conditions evidently were more favorable, a second whirl developed, made contact with the earth, and it, too, disappeared after a course of 40 miles. In each case movement toward the northeast brought the whirl into regions of lower temperature and, possibly, less moisture content. This action was again repeated in the case of the (f) tornado, which originated in Marion County, Ky., and moved as before described.

The observations on the (d) tornado were especially worth while; they confirm the suggestion by Root, previously mentioned, with respect to the lower end of the pendant funnel cloud. Following is a brief account of this tornado, with excerpts from Kendall's report.

[2] Annual Report, Chief of Weather Review, 1895-96, p. xxiv.

[3] The occasional lifting of the funnel cloud and losing contact with the earth may be considered as an indication of the more or less imperfect development of the whirl.—ED.

The tornado originated in Harrison, County, Ind., moved thence east-northeast in a path about 40 miles long and of varying width. The effect of rising ground on the pendant funnel cloud is discussed as follows:

* * * The district traversed rises in a rolling plateau, with the highest part a rather abrupt escarpment on the eastern edge, along the Ohio River, where the elevation averages about 850 feet above sea level. With the increasing elevation the funnel of the tornado became more and more deeply truncated, which caused the path of practically total destruction to widen to about half a mile. At the edge of the plateau along the Ohio River, where the descent is very abrupt, being about 400 feet in as many yards, the funnel dipped down immediately and destroyed all buildings in its path, even at the foot of the bluff over which it had come. At this point the path narrowed to about 900 feet; it narrowed further in crossing the Ohio, but widened again to more than 1,000 feet as higher ground was reached about 2 miles to the eastward, after which it generally contracted until it was only 50 feet wide at Pewee Valley.

* * * At the time of its passage the center of the low-pressure area was near Indianapolis. Immediately after the passage of the tornado at Louisville the skies cleared, the air became calm, and the temperature rose about 8° * * *.

Mr. Kendall notes that this tornado passed through Harrison County near Elizabeth, within less than 2 miles of the path of the severe tornado of May 27, 1890, which, it may be remembered, struck Louisville, causing great loss of life and property.

The Louisville barograph shows frequent oscillations from about 7:30 a. m. to 4 p. m., or just before the passage of the tornado. The lowest point on the Louisville trace was reached at 6 p. m., which corresponds pretty closely with the time of the passage of the cyclone center about 115 miles to the north.

ABILITY OF MODERN STRUCTURES TO WITHSTAND TORNADOES

Much interest is evident in recent years in the ability of well-constructed buildings of brick, stone, concrete, or what not, to withstand the terrific force of the wind as exerted in tornadoes.

Photographs of the destruction in various parts of the tornado path seem to show that light frame structures, which abounded in the towns and villages of southern Illinois, were totally demolished, although in a few cases the framework of the buildings held together even when the building was swept from its foundation.

The damage to school buildings of brick construction was particularly noticeable; the roofs were ripped off and the upper stories badly wrecked.

A correspondent of Engineering News-Record, writing in the issue of March 26, mentions the fact that at Murphysboro, while a clean sweep was made of structures in the northwest part of the city, two reinforced concrete coal bins within 300 feet of the Mobile & Ohio Railroad shops, which latter were destroyed, were left standing undamaged in the midst of a mass of wreckage. Also near the railroad shops two steel wheat bins * * * are still intact, although one of them is leaning. The brick building of the Brown Shoe Co. in Murphysboro was damaged considerably. Immediately in the rear is a 160-foot reinforced-concrete smokestack. In spite of the great amount of destruction around this structure, it remains standing and shows no signs of damage whatever. A small two-story building of plain concrete was practically destroyed, its 8-inch walls being sheared off entirely at the top of the first floor.

Root and Barron, in a supplemental report on damage to buildings, say:

Frame dwellings.—Unless well built, largely totally demolished in main path of tornado. A house in Griffin, Ind., lying on its side was returned to its original position by workmen practically intact. It had diagonal sheathing, which added much strength. Of houses not destroyed, the roofs and porches were taken off and in some cases the second story.

Stucco residences.—An architect in Murphysboro invited our attention to the fact that stucco houses resisted the storm to best advantage, and we found from observation that they did stand up better than frame buildings. There were few stucco houses except in Murphysboro. (We saw none.)

Brick buildings—Schools.—For the most part in two-story brick schools the first floor walls remained practically intact; in the second story the interior walls largely remained standing, though the outer walls crumbled. The Mobile & Ohio shops at Murphysboro, brick buildings, were demolished by wind and afterwards burned. In general, brick store buildings in the direct path of the storm were destroyed. A new brick two-story mine office building at Orient No. 2 mine at West Frankfort was practically undamaged, but it was in the lee of the large steel mine tipple. To the best of our memory, brick buildings stood up where they had steel trussed roofs.

Steel construction.—Steel water and oil tanks belonging to the railroad at Gorham were unharmed. A similar steel water tank at West Frankfort mine was blown over. At the same mine (Orient No. 2) the steel conveyor was badly damaged, but the large modern steel tipple was not greatly harmed. The tipple at Caldwell mine (wood and steel) was demolished.

THE TORNADO OF APRIL 5, 1925, NEAR MIAMI, FLA.

By RICHARD W. GRAY

[Weather Bureau Office, Miami, Fla., April 15, 1925]

The destructive tornado which passed north of Miami during the early afternoon of Sunday, April 5, 1925, occurred in connection with a disturbance that had moved southeastward across the United States from the California coast and that was central over extreme northern Florida at the time of the tornado.

The tornado developed over the Everglades, apparently in the vicinity of Hialeah, which is about 4 miles northwest of the city limits of Miami and about 8 miles northwest of the Weather Bureau station. The funnel cloud was first observed by golf players on the municipal golf course at Hialeah at 1 p. m. or a few minutes earlier. Its development was also seen by many other persons whose attention had been attracted by the unusually threatening sky which attended a thunderstorm and hailstorm preceding the tornado. The opportunities for observing the storm were exceptionally favorable. The usual large Sunday crowd was out of doors, many hundred automobilists being near the tornado path. Moreover, on account of its slow progress, word of the tornado was widely spread and several thousand persons watched it until it disappeared.

Many observers stated that the development of the tornado immediately followed the uniting of two dense cloud masses. When first seen by the writer, at 1:15 p. m., the development was complete, and the funnel cloud appeared as a very slender cone extending in a straight line from the dense cloud mass above to the earth. With the exception of a slight bending and twisting of the lower part of the cone, there was no deviation at any time from the vertical position of the funnel cloud. This was undoubtedly due to the slow movement of the general cloud mass. The funnel cloud, however, frequently rose from the ground only to descend again within a few minutes. When its end touched the ground there invariably followed a phenomenon similar

to that caused by the explosion of a high-powered shell. The air surrounding it for a considerable elevation above the ground was immediately filled with dust and débris which, at a distance, appeared like dense smoke from burning oil.

After the storm had been in progress for about 20 minutes it stopped its progressive movement for five minutes. Until it resumed its northeastward course the writer thought it had turned to the northwestward and was moving directly away in the line of vision. Its location at this time was over a large dairy, where one person was killed and one fatally injured and where 20 others were injured. The loss at the dairy from the destruction of buildings, motor trucks, automobiles, and livestock was estimated at $100,000. The funnel cloud rose and descended twice during the stationary period, causing the less severely injured persons at the dairy to think that a second tornado followed closely behind the first.

After the storm resumed its northeastward course it passed over several suburban communities northwest and north of Miami, wrecking many residences, killing or fatally injuring three persons, and injuring many others. Several persons escaped injury and probable death by deserting their automobiles and fleeing. The automobiles were destroyed, some of them being picked up and carried for a considerable distance through the air.

By the time the storm had reached a position directly north of Miami the funnel cloud had increased greatly in diameter and it was soon afterwards obliterated by heavy rain between Miami and the path of the storm. No serious damage was done after this time, and the tornado formation apparently dissipated over the extreme northern part of Biscayne Bay. In the eastern end of the path prostrated poles lay with their tops toward the southwest, showing the effects of the whirling motion.

The path of the storm averaged less than 100 yards in width, and many buildings and trees immediately outside of it were uninjured. Buildings left standing in the path showed where the cloud rose from the ground.

The tornado was preceded by a heavy fall of hail, which was confined principally to the tornado path. In some localities the ground was completely covered, and hail stones were reported as large as a baseball or a man's fist. Many were measured that were 3 inches in diameter. Hailstones perforated the tops of automobiles and damaged the roofs of some houses.

The instruments at the Weather Bureau station at Miami were not affected by the storm. Light southeast winds prevailed at the station during the forenoon of the 5th and until after the tornado had disappeared. As the tornado was carried along in a southwest current, it is evident that it occurred along the wind-shift line of the general disturbance. The pressure at Miami fell gradually until shortly after 2 p. m., when the wind-shift line passed over the station, attended by a thunderstorm with characteristic rise of pressure and a decided increase in wind force. The maximum velocity recorded was 24 miles per hour, from the west, at 2:20 p. m. This was after the tornado had disappeared. The slow movement of the wind-shift line accounts for the slow progress of the tornado, which required approximately one hour to move the 12 miles from Hialeah to the northern part of Biscayne Bay. There were no fluctuations of pressure at the Weather Bureau station during the progress of the tornado.

The storm caused the death of five persons and the destruction of much property. About 35 persons were injured and received treatment in local hospitals, while others, less severely injured, were treated in private dwellings. The estimated property loss was between $200,000 and $300,000.

OCEAN TEMPERATURES ACROSS THE EQUATOR

By W. J. HUMPHREYS

Everyone is accustomed to the well-known and obviously reasonable fact that the highest average annual temperature over extensive land areas occurs along or near the Equator. He is surprised, therefore, when he learns that, in general, the highest temperature of the ocean at every depth, save near the surface, is at 30°, roughly, north and south of the Equator. As the surface is approached from a depth of around 400 meters these maxima rapidly draw closer together, but do not merge even at the surface.

At every depth from 50 to 1,000 meters, or thereabouts, the equatorial water is approximately 5° C. colder than the warmest water at that level both north and south. As the depths become abysmal this contrast, though still present, is very slight, the temperature everywhere being of the order 1° to 3° C.

Most of these facts are shown graphically in Figure 1, a thermal cross section of the Atlantic Ocean at 30° W.[1]

Evidently this temperature distribution is owing essentially to the gradual sinking of water in the latitudes 15° to 40°, perhaps, north and south, and the slow upwelling of the ocean in the equatorial regions. This circulation in turn, however, seems to be the result of several factors:

1. Around latitudes 20° to 35° the skies are comparatively clear and evaporation in excess of precipitation.

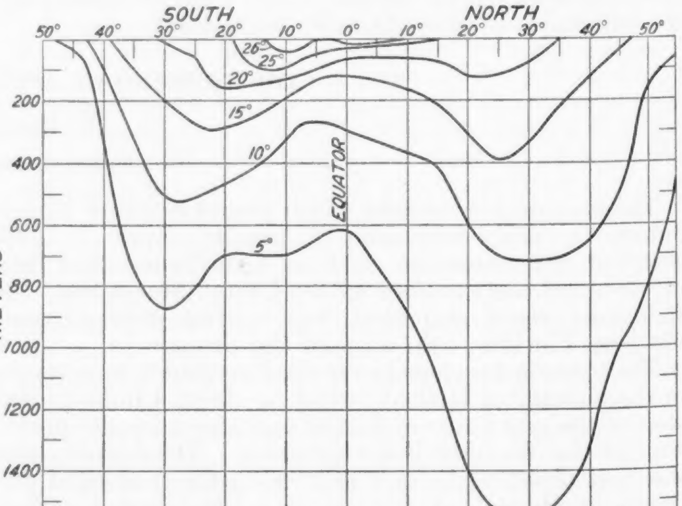


FIG. 1.—Temperature cross section of the Atlantic Ocean at longitude 30° W.

This increases salinity and, thereby, the density, which, of course, leads to sinking.

[1] Adapted from Tafel 28, Deutsche Tiefsee-Expedition, 1898–99, *Wiss. Ergeb.*, Band I, Atlas.

2. Near the Equator the sky is largely clouded and precipitation in excess, apparently, of evaporation, the excess coming from evaporation at higher latitudes. This leads to more or less dilution, decrease of density, and upwelling.

Both these causes, (1) and (2), are well known and generally accepted. There is a third factor, however, contributory to the result which I have not seen mentioned in this connection, namely:

3. The Ekman drift: As first shown by Ekman,[2] in the case of deep water far from land a steady wind produces a surface drift 45° to the right in the Northern Hemisphere, to the left in the Southern, of the direction of the wind with reference to the moving surface. But the velocity of the driving wind is thirty to thirty-five times that of this surface, hence the direction of the wind with reference to the water is substantially the same as its geographic direction. Furthermore, the total momentum of the moving water, mainly less than 50 meters deep, is at right angles to the direction of the wind with reference to the adjacent water. Therefore, since the equatorial winds generally are from the east, and the winds of higher latitudes than 35°, say, from the west, the momentum of the resulting Ekman drift is substantially poleward from low latitudes and equatorward from places beyond about 30° north and south. This force evidently tends to pile up the surface water along the belts between the oppositely-directed winds and therefore is a contributing cause of the continuous sinking of the water in these regions and its equally continuous upwelling along the equatorial belt.

Finally, since on the whole the surface temperature decreases from the Equator toward either pole, while the surface sinking covers rather wide belts centered roughly along latitudes 30° north and south, it follows that, for a considerable distance down, the belts of maximum temperature must recede from the Equator with increase of depth, as shown in the figure.

The surprising distribution of ocean temperature described above is, therefore, for the most part, an interesting meteorological effect.

[2] *Arkiv för Mat. Astr. och Fysik*, 1905.

EFFECT OF LOCAL SMOKE ON VISIBILITY AND SOLAR RADIATION INTENSITIES

By Irving F. Hand,

[Weather Bureau, Washington, D. C., April 22, 1925]

The dense smoke cloud which covered the northwest section of Washington on the morning of April 7, 1925, was remarkable in so many respects that it is thought worthy of a brief description.

On that date the sun rose in a cloud-free sky with prospects for an excellent day for obtaining solar radiation observations. Heavy frost, a minimum temperature of 32° F., and ice one-half inch in thickness were recorded.

When pyrheliometric readings were first made at 6:40 a. m. the Blue Ridge was plainly visible 50 miles to the WSW. At that time little attention was paid to the rather streaked layer of smoke which overhung the business section of the city, as such layers are of somewhat frequent occurrence. However, this one was rather unusual in that its top was perfectly flat.

Half an hour later it became apparent that the solar radiation observatory, which is located on the American University campus, 5 miles NW. of the Capitol, would soon become enveloped in a smoke cloud. Coincident with the arrival of this cloud at 7:30 a. m., the visibility diminished until at 8 o'clock, the time of maximum covering, it had decreased from 50 miles to three-quarters of a mile.

Observations of the number of dust particles per cm.[3] taken at 8 a. m. and at noon give values of 7,077 and 166, respectively. This former value exceeds by 17 per cent the previous Washington maximum, obtained at the Central Office of the Weather Bureau in January, 1924, while it is nearly three times the previous maximum obtained at the American University. It is approximately the number obtained in the Loop District of Chicago on a moderately smoky day—a statement which means much to anyone familiar with that city. The noon value, 166, is below the yearly average of all observations, and about the mean value obtained with a visibility of 30 miles, which was that noted at the time.

An examination as to the character of the dust particles showed that the first record obtained was composed almost entirely of soot, unconsumed carbon, and other products of combustion; many tiny glassy spheres with an average diameter of about 0.0008 mm. being included in the latter. The particles on the noon record were not only smaller but showed almost no soot.

Table 1.—*Distribution of meteorological elements*

Time	Temperature	Relative humidity	Vapor pressure	Visibility	Wind		Clouds, amount and kind
					Velocity	Direction	
	°F.	*Per cent*	*Inches*	*Miles*			
6 a. m.	32	87	----------	50	1	NW.	0
8 a. m.	38	83	0.187	¾	2	SW.	0
Noon	57	20	0.089	30	7	S.	1 Ci.

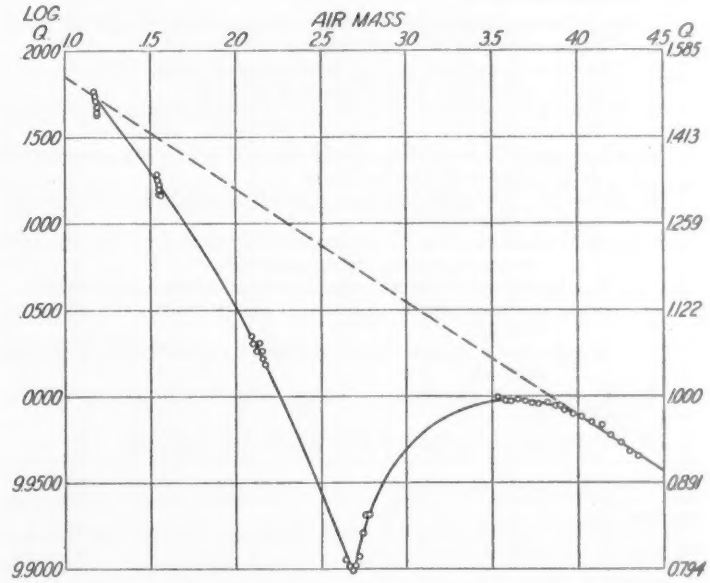


Fig. 1.—Solar radition intensities, American University, D. C., April 7, 1925, showing the effect of local smoke

As will be seen from Table 1, the visibility at noon was but 30 miles as compared with 50 during the early morning, but this is due, in part at least, to greater diffusion of light with increased altitude of the sun and to a background of clouds west of the Blue Ridge.

The curved line on Figure 1 represents the trend of solar radiation intensities measured at normal incidence during the morning of the 7th, logarithms of intensities (log. Q.) being plotted as abscissæ against air mass (approximately the secant of the sun's zenith distance), as ordinates. The broken line has been drawn by interpolation between the first and last series of observations, taken before and after the passage of the smoke cloud, respectively. Extrapolating this to zero air mass we obtain for the value of log. Q., 0.2500, which indicates that the line is representative of what would have been expected with a smoke-free sky.

Table 2 shows not only a decrease of 34 per cent at air mass 2.68, but an actual diminution of 19 per cent with decrease in air mass from 4 to 2.68, a rare occurrence in Washington.

Considering that Washington is not a manufacturing city, the localization of this smoke from heating plants, etc., is most unusual; in fact, the smoke cloud was by far the densest ever observed by the writer during the 10-year period he has been stationed at the American University.

TABLE 2.—*Solar radiation intensities, April 7, 1925*

(Gram-calories per min. per cm.²)

Air mass	Intensities measured through smoke	Intensities from interpolated line	Decrease due to smoke
			Per cent
1.18	1.49	1.49	0
1.58	1.33	1.41	6
2.10	1.08	1.30	17
2.68	0.79	1.19	34
4.00	0.97	0.97	0

SEASONAL PRECIPITATION IN CALIFORNIA AND ITS VARIABILITY [1]

By BURTON M. VARNEY

[U. S. Weather Bureau, Washington, D. C.]

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PART I

I. INTRODUCTION

1. Significance of the relations between precipitation and water supply in California.—Probably in no State in the Union is the water problem more pressing than in California. Without going into extensive detail concerning the intimacy of the relation between rainfall and human activity there, it may be pointed out that the

[1] A dissertation submitted to the graduate board of Clark University, Worcester, Mass., in partial fulfillment of the requirements for the degree of doctor of philosophy, February, 1925.

Acknowledgments.—To Dr. Charles F. Brooks, for his many helpful suggestions during the preparation of this paper.
To the trustees of Clark University, for the award of a $200 graduate scholarship carrying remission of tuition fee.
To the research board, University of California, for a $200 grant from the research fund of the university.
To the officials of the United States Weather Bureau office at San Francisco, Mr. E. A. Beals in charge, for assistance in the assembling of the fundamental data.
To Mr. Allen W. Jacobs, University of California, special acknowledgment is due for his painstaking assistance in assembling, checking, and computing the data which form the basis of this study.

density of population, as expressed in terms of demand upon the water resources of the State, is already such that a few consecutive seasons of scant rainfall and snowfall entail serious consequences. Ample comment upon this fact is furnished by the results of the great drought of 1923-24, which was the culmination of a series of seasons in which the rainfall had been generally and in many regions seriously deficient.

While the agricultural significance of rainfall for California has often been emphasized,[1] it is instructive to note that, contrary to general impression, there is literally no part of the State where, in the opinion of those most familiar with conditions, the agricultural lands would not be benefited by irrigation.[2] This strong statement does not recognize as an exception even the northwestern coastal area, where seasonal rainfalls range from 30 and 35 inches upward. In this area in 1920 there were 22,300 acres under irrigation, and the estimated average desirable amount of water over and above that supplied by rainfall directly is 15 inches annually. Still more striking is the estimate that irrigation is here desirable in seven months of the year, distributed in amounts of 10 per cent or more of the total through six months. This being expert opinion regarding an area generally thought of as abundantly supplied with rainfall, the importance of precipitation for the eleven and two-thirds millions of acres of improved farm lands in the State, four and one-half millions of which are under irrigation, needs no further comment.

The natural pasture lands of the State are equally dependent upon rainfall. Cattle owners have often faced the alternative of heavy if not ruinous expense for transporting stock to temporarily better watered grazing lands outside the State, or, as has happened time and again, of seeing that stock die by the thousands for lack of water and feed.

Excessive rainfall is sometimes as destructive as drought, though now to a lesser degree than in the past, owing to better river control. The wheat farmers who annually seed thousands of acres in the usually dry bottoms of Tulare Lake in the southern San Joaquin Valley do so in the face of a probability of damage from floods which is so great that only the high fertility of the land justifies them in taking the risk. The damage which flood waters do in the Tulare bottoms is conditioned as to time, duration, and place of occurrence by intricate combinations of factors, the operation of which may lead in some cases to widespread damage, in others to very little damage, and in yet others to damage to some fields and benefit to others.[3]

What these combinations are, and how often or when they are likely to occur, has not yet been worked out. This will be possible only when full knowledge of rainfall and run-off conditions combined can be applied to the solution of the problem.

It is clear, then, that so far as precipitation is concerned the solution of the water supply problem for California lies not only in knowing the seasonal averages of rainfall for all parts of the State, but also its seasonal variability, the mean departures of seasonal precipitation, the frequencies of occurrence of departures of stated amounts, the most frequent amounts of total seasonal precipitation to be expected, and so on.

2. Types of investigation previously undertaken.—Fluctuations of rainfall and snowfall over the area have been studied from four general points of view. One of these is illustrated by the researches of Douglass and of Huntington[4] on evidences shown by tree growth concerning variations in precipitation during prehistoric and historic times; another by the investigation carried out by William G. Reed[5] on fluctuations from year to year since the beginning of Government rainfall records; another by the work of McEwen[6] on forecasting departures of seasonal precipitation from the average through the study of variations in ocean water temperatures; while the fourth point of view, exemplified by the precipitation studies in the Atlas of American Agriculture,[7] includes the investigation of the areal distribution of variations in rainfall. In the nature of the case, the mapping and discussion last mentioned deals with California only as a small part of the United States, and therefore only in a general way.

3. Purpose of the present study.—The present study is intended to carry this type of investigation into detail commensurate with the importance of the water problem in that particular area. Its purpose is to find what the past measured fluctuations of rainfall have been, and on this basis to express what may be called the *reliability* of precipitation in ways which it is hoped will prove useful to investigators not only in the field of climatology but in other fields as well.

This type of work should proceed only on the basis of data gathered under the direction of recognized authority from instruments exposed under standard conditions and therefore giving results which are believed to be as nearly comparable as it is possible to make them. On this account the data used in the present study were taken entirely from the Summaries of Climatological Data by Sections published by the United States Weather Bureau,[8] and extended to the end of the rainfall season 1919-20 by transcript from station records filed in the San Francisco office of the Weather Bureau since the ends of the periods covered by the section reprints.

Before discussing the work of preparing data on the problem the following definition of terms as here used should be made:

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[1] See Palmer, Andrew H., in Mo. WEATHER REV., as follows: Region of Greatest Snowfall in the United States: 1915, May, **43**: 217-220. Relation of Climate to Agriculture in California: 1915, August, **43**: 398-400. Water Supply in California (abstract): 1919, May, **47**: 311. The Drought in California: 1920, March, **48**: 156-157. Economic Results of Deficient Precipitation in California: 1920, October, **48**: 586-589.

[2] A thorough survey of the relations of water supply to agriculture in California is comprised in Bulletins 4, 5, and 6, Division of Engineering and Irrigation, Department of Public Works, State of California. Bulletin 4, "Water Resources of California," outlines the problem and discusses a comprehensive plan for its permanent solution. Bulletin 5, "Flow in California Streams," being Appendix A to Bulletin 4, contains a wealth of detail in discussion, together with 175 tables and 185 plates. Bulletin 6, "Irrigation Requirements of California Lands," being Appendix B to Bulletin 4, contains detailed discussion, together with 11 tables and 7 plates. Plate 4 of this bulletin is a rainfall map of California, on which 726 precipitation stations are entered, including the total available number of Federal, State, and private stations. Their records form the basis for drawing the isohyets of average seasonal precipitation. 336 of the stations had at the end of the period used, records of less than 10 years and 216 of 5 years or less. All are adjusted to a uniform period of 50 years. Out of the 726 stations used, 16 had an actual record of 50 years or over.

[3] Information by letter from the Division of Engineering and Irrigation, Department of Public Works, State of California. Bulletin 5 (*loc. cit.*), p. 423, Plate LXVII, gives a graph showing probable frequency of flood discharge in the Tule River, the principal affluent of Tulare Lake.

[4] Douglass, A. E., Climatic cycles and tree growth; a study of the annual rings of trees in relation to climate and solar activity. Washington, Carnegie Institution of Washington, 1919.

Huntington, Ellsworth, The climatic factor as illustrated in arid America. (With contribution C. Schuchert, A. E. Douglass, and C. J. Kullmer.) Publ. Carnegie Inst. of Washington, No. 192.

[5] Reed, W. G., Variations in rainfall in California. Mo. WEATHER REV., 1913, November, **41**: 1785-1790.

[6] McEwen, George F., How the Pacific Ocean affects southern California's climate: Seasonal rainfall for 1923-24 indicated by ocean temperatures.

Bull. Amer. Meteorol. Soc., IV, October, 1923: 142-148. See also: The distribution of temperatures and salinities, and the circulation of the North Pacific Ocean.

Bull. of Scripps Inst. for Biol. Research of the University of California, No. 9, Dec. 15, 1919: 59-64.

[7] U. S. Department of Agriculture, Atlas of American Agriculture; Part 2, Climate; Section A, Precipitation and Humidity, by J. B. Kincer. This publication contains a bibliography.

[8] U. S. Weather Bureau Bulletin W, Washington, 1912. Reprints from Bulletin W for the California area bring the data down to more recent years, as follows: Section 13, Southern California and Owens Valley, annual values to 1919, seasonal values to 1918-19; section 14, Central and Southern California, annual values to 1911, seasonal values to 1911-12; section 15, Northeastern California, annual values to 1919, seasonal values to 1918-19; section 16, Northwestern California, annual values usually to 1917, seasonal values usually to 1916-17.

Rainfall, following the usage of the United States Weather Bureau in its climatological work, includes rain and all other forms of precipitation, expressed in terms of their water equivalent. *Seasonal rainfall*, is the precipitation recorded as having fallen between July 1 of one year and June 30 of the next, inclusive.

4. Annual v. seasonal rainfall in California.—The calendar year is an unsatisfactory unit for use in the California area, where much of the industry of the State is dependent on the subtropical régime of rainfall. The calendar year, however, would be suitable for the purposes of the present discussion if extended comparisons with other parts of the country were contemplated. A year beginning October 1, sometimes used by irrigation engineers in California,[9] is so used because it fits fairly closely the yearly period of stream discharge in the area, where approximately 55 per cent of the streams show a minimum discharge in September and about 95 per cent a minimum in August, September, or October. But this division does not fit the yearly period in rainfall in which the well-known summer minimum for the State as a whole not only separates the rainy seasons, but above all, clearly delimits the seasons of the major cereal crops, with the exception of corn.[10] Thus the seeding of winter wheat is done during the onset of the rainy season in September, October, and November, in general earliest in the north and latest in the south, in response, not to a temperature control as in the eastern part of the country, but to the later beginning of the rainfall season in the southern part of California than in the north. Harvesting of the winter wheat occurs from May to August, being earliest in general in the south and latest in the north. The seeding of spring wheat is a late winter and early spring operation and the harvest a midsummer one following that of the winter wheat. Winter oats are sown in the late autumn and early winter and harvested from April to July, both operations varying in time in different parts of the State.

In the grazing and feeding practice in California the same seasonal character is evident. Winter and spring largely comprise the growing season of the range grasses; consequently this is primarily a region of winter and spring range feeding, at the end of which much of the livestock in the State is transferred from range to ranch for feeding during the summer and autumn. The length of the season on the range, and hence the period during which it is necessary to feed stock, fluctuates within wide limits, depending on the interaction of the factors (rainfall and temperature being the most important) which cause seasonal variations in the carrying capacity of the range.[11]

From the point of view also of the meteorological controls of the California rainfall season, this is a region where the annual rhythm in the number and intensity of cyclones, which are responsible for the rainfall, is characterized by a season of activity extending from the latter part of one calendar year into the early part of the next. Hence the wetness or the dryness of a "season," a thing determined by fundamental differences from one year to another in the character of the annual southward migration of the belt of stormy westerlies over California, can not legitimately be thought of as applying to the second half of one rainy season and the first half of the next. It is clear, then, that both with respect to its cause and as regards its relation to important human activities in the State the rainfall season is a unit, separated from the preceding and following seasons by periods of summer drought.

II. PREPARATION OF DATA FOR THIS STUDY

1. General statement of the problems involved in selecting precipitation stations.—Decision as to what stations should be used as a basis for the work depended, first, on the length and continuity of the available records, and, second, on what uniform length of record it seemed best to adopt. These items may be treated together.

The ideal record for a region as complicated topographically as is California would be that obtainable from a group of closely distributed stations which had been in continuous operation with unchanging conditions of instrumental exposure over a long period of years. How long this period should be in the case of California and what the relation is between the ideal conditions and the practical problem of selecting stations and length of period depends on several factors which may now be discussed. The size of California, her sharply contrasted topographic and climatic features, and the unequal progress of settlement in her various parts have led not only to great diversity in length of rainfall record but in many cases also to a lack of continuity in it, both in time and area. Combined with these conditions is the fundamental one that the correctness of average seasonal values to within a stated percentage of probable error depends on the two factors: length of record and the amount of the average departure of the individual seasonal totals from the average of those totals. That is, the shorter the record and the greater the average departure the greater is the probable error of the average values.

2. The probable error of averages based on given data.—Hann[12] has discussed at length, on the basis of European records, the bearing of these factors on the reliability of meteorological averages in general. The conclusions to be drawn from his discussion form an important comment on the reliability of averages derived from seasonal rainfall records for California—and for most parts of the United States where records are short and variabilities high. For a group of three central European stations having 176 years, 88 years, and 100 years of record, respectively, the average departures of the annual rainfalls of various short periods from the long period average are as follows:

Average of	5 years	10 years	20 years	30 years	40 years
Average departure in percentage of long-period average	8.7	7.5	5.2	2.6	2.3

Furthermore, on the basis of the average departures of the annual totals for western and central European

[9] Proposal was made by C. E. Grunsky that the U. S. Weather Bureau publish precipitation data on the basis of a year beginning either September 1 or October 1, but since rainfall data for California were already being printed on the basis of a year beginning July 1 it was deemed inadvisable to adopt the proposal, particularly since international usage adheres to the calendar year.

[10] See Baker, O. E., Brooks, C. F., and Hainsworth, R. G., A graphic summary of seasonal work on farm crops.
U. S. Dept. of Agric. Yearbook, 1917: 539-589, especially maps 11-35.

[11] J. Warren Smith has emphasized the fact that the seasonal distribution of rainfall seems to be more important in the grazing problem in California than is the seasonal total. Seasons with rainfall above normal may at the same time be bad seasons for stock if the rainfall is concentrated in a few weeks instead of being spread through several months. This is especially true if the rains following the summer dry season are very late in beginning. "In one section of the Santa Barbara National Forest in southern California the rainfall in 1918 was about 21 inches, but instead of being well distributed through the winter months it did not come until February. It was not followed by good spring and early summer rains; as a result ranges carried only about one-third as much stock as usual. *A little more than one-half as much rain well distributed would have given far better results.*" (Italics mine.—B. M. V.) See Smith, J. Warren, Relation between the annual precipitation and the number of head of stock grazed per square mile.
MO. WEATHER REV., 1920, June, 48: 311-317.

[12] Hann, J., Lehrbuch der Meteorologie, 3rd ed., 1915: 110-113.

stations being 13 per cent of the annual average, the probable error of averages based on periods of various lengths is given as follows:

Average of	30 years	40 years	50 years
Probable error, per cent	2.0	1.7	1.5

Discussing the fact that the probable error also decreases with the lessening of the average departure of the annual totals from the mean values, Hann quotes the following formula of Fechner [13]

in which, if v = mean departure from the annual mean,
n = number of cases on which the departure is based,

then the probable error of the arithmetical average in percentage of the true average is

$$\frac{1.1955}{2n-1} \times v.$$

3. The probable error of averages for California stations.—It is interesting to note first the changes in the seasonal rainfall averages based on records of various lengths at Sacramento in the following Table 1. This station is chosen because it has a record of over 70 seasons in length. San Francisco or San Diego, with records of similar length, would have served equally well.

TABLE 1.—*Relation between magnitude of rainfall averages and length of record, Sacramento, Calif.*

Length of record ending 1919–20	Seasons	Average rainfall	Departures from average of 71 seasons	
			Inches	Percentages
		Inches		
From 1849–50	71	18.75		
1855–56	65	18.42	0.33	1.8
1865–66	55	18.65	.10	0.5
1875–76	45	18.51	.24	1.3
1885–86	35	17.87	.88	4.7
1895–96	25	16.74	2.01	10.7
1900–01	20	16.61	2.14	11.4

This table makes clear the facts that the shorter periods give means considerably lower than those for longer periods, that there is a progressive increase in the means up to 45 seasons, that the increase in the length of period between 45 and 71 seasons does not result in any further progressive reduction of the departure from the average of 71 seasons, and that the average apparently lies somewhere between 18 and 19 inches. Further evidence is furnished by applying Fechner's formula to the Sacramento data in order to find the probable error. The average departure of the seasonal rainfall from the 71 season average, v being 28.6 per cent of the average, which is more than double the 13 per cent given by Hann for western and central European stations, and n being 71, the probable error is

$$\frac{1.1955}{141} \times 28.6 = 2.4+ \text{ per cent.}$$

It is to be observed that this error of a 71-season average is nearly half again as great as that of a 30-year average for European stations where the average departure is less than half that at Sacramento. For 25 seasons at Sacramento ending 1919–20 the average departure from the mean of that period being 25 per cent, the probable error is 4.3 per cent, or more than twice that of the 30-year average above referred to. In other words, it appears that even 71 seasons of record at Sacramento are insufficient to establish reliable averages. What bearing have these results on the reliability of averages based on California records in general?

If it had been found practicable to compute the average departure for each station on the basis of its entire period we should then have had the best basis for finding the probable errors. This being not the case, it was decided to compute the departure for a 25-season period ending 1919–20 for each station having a record of this length or over. There are 82 such stations. The average of these average departures was then found to be 26.1 per cent, or 1.1 per cent greater than the departure at Sacramento for the same period. The probable error for the State as a whole is therefore 4.5 per cent of the 25-season mean, as against 4.3 per cent for Sacramento.

The question may legitimately be raised as to whether the distribution of these 82 stations is such that they truly represent the whole State. They have been segregated because they are the only ones having 25 seasons of unbroken record. They show the facts for the longer-settled portions of the State. There were in addition at the end of the season 1919–20, 103 stations with records 10 to 24 seasons long. Particularly for certain desert and mountain areas of the State, these records, short as they are, help tolerably well to fill out the map of station distribution.

A satisfactory statement of the mean of their average departures can not be made, either on the basis of their unequal lengths of record or of these records adjusted to a uniform period. Of the 104 stations, however, 82 are so located with reference to others having 25 seasons of record that it is believed their averages may properly be adjusted by comparison with these 25-season stations. This adjustment has been made and, with full recognition of the fact that short periods so adjusted form by no means a perfect basis, but merely the best one obtainable, for estimating what the average departures would be if these stations had 25 seasons of record, this average departure is presented for what it is worth by way of comparison with the mean of the average departures of the "long-period" records. The value is 25.3 per cent. Averaging this with the 26.1 per cent for the long-period stations, we have for 164 stations an average mean departure of 25.7 per cent. With the qualification above noted, this figure may confidently be taken as reliable, because while there are many areas of the State not represented (those for which there are no Government records and those containing stations left unadjusted by reason of their remoteness) nevertheless, every type of California terrain is represented, whether mountain or plain, humid land or desert, high altitude or low. Moreover, the cyclonic control of rainfall, which is the immediate cause of its seasonal variability, is, as will be evident later, exerted in similar fashion over large areas. Hence it is believed the inclusion of regions now excluded would make no important difference in the above figures. A mean of the average departures of 25.7 per cent from the mean of the 25-season average rainfalls indicates a probable error for the State as a whole of 4.2 per cent.

It will be noted at once that these figures, being averages, totally lack the ability to portray the variations in average departures and consequently in probable errors which occur in the data for California stations. For the

[13] Ibid., p. 112.

sake of the light it throws on these variations and on the vagaries of California rainfall in general, Table 2 is presented. The average departures for 164 stations (the records having been adjusted where necessary, as noted above) were arranged in groups, with departures of less than 15 per cent in one group, 15 to 19.9 per cent in another, 20 to 24.9 in another, and so on. The fourth line of the table shows the mean probable error for each group, based on the uniform period of 25 seasons and the average departure of the group from the 25-season average.

TABLE 2.—*Average departures and probable errors (both in percentages of the average seasonal rainfall) for 164 stations in California*

Departure (per cents)	Less than 15.0	15-19	20-24	25-29	30-34	35-39	40-44	45-49	56	57.5	70
Number of stations	2	25	62	46	18	5	2	1	1	1	1
Average departure	14.2	18.6	22.6	27.4	31.8	35.8	40.9	46.5	56	57.5	70
Probable error	2.5	3.2	3.9	4.7	5.4	6.1	7.0	8.0	9.6	9.9	12

A study of this table brings out the facts that only about one-sixth of all the stations have less than a 20 per cent annual mean departure, that about three quarters have between 20 and 25 per cent, and that about one-twelfth have over 35 per cent. Furthermore, it is evident that when the mean departures are based on a 25-year period the probable errors of the means rise rapidly as the departures increase. And when, in addition, the length of the period is very short the extent to which probable error increases is such that great care must be used in drawing conclusions from the data. The facts suggest that if one were to go into details he would find a plenty to disturb his faith in rainfall averages based on short records showing high variability and not adjusted by reference to stations with long records. It is a point not infrequently disregarded by lay users of climatological data that the comparing of means not so adjusted is all but futile.

4. Criteria for the selection of precipitation stations.—The above discussion indicates that the choice of stations and of uniform period to which all the records were to be reduced depends largely on factors other than the reliability of the averages. In other words, if 71 seasons of record at Sacramento give a rainfall average with a probable error of 2.4+ per cent, then it is useless to expect high reliability in averages from other records in the State. The matter thus resolves itself into the selection of a uniform period which shall meet two needs—that of having the *period as long as possible*, and that of providing *enough stations having this length of record to assure a distribution of them in relation to stations with less than this length, such that the adjustment of the latter to the uniform period shall be valid.* The period of 25 seasons from 1895–96 to 1919–20, inclusive, was chosen. The number of stations having more than this length falls off rapidly above 25 seasons—more rapidly in some parts of the State than in others—with the result that their distribution soon becomes highly unsatisfactory. It is felt that the period of 25 seasons represents the limit of safety, so to speak, for most of the State. The 82 stations having records of this length ending 1919–20 will be designated hereafter as "long-period stations." (See Table 3 and fig. 1.) The numbers of these are greatest in the longest-settled parts of the State, the most conspicuous of which include the region centered at San Francisco Bay, the Great Valley, the mining region on the lower west slope of the Sierra, particularly in the north central part, and the long-settled region of southern California west of the desert. Within these areas the distribution of long-period stations at least approaches the ideal. The same can not be said of the remaining portions of the State.

TABLE 3.—*Alphabetical and numerical identification list of 82 rainfall stations having 25 seasons of record ending 1919–20, to accompany map of stations in Figure 3.*

ALPHABETICAL LIST

Antioch	36	Oakland	41
Auburn	29	Orland	11
Bakersfield	66	Oroville	20
Berkeley	40	Paso Robles	60
Cedarville	2	Placerville	31
Chico	9	Point Reyes	38
Claremont	72	Porterville	64
Colfax	28	Quincy	8
Cuyamaca	80	Red Bluff	7
Davis	17	Redding	6
Durham	10	Redlands	74
Eureka	4	Represa	32
Folsom	33	Rio Vista	35
Fordyce Dam	23	Riverside	75
Fort Ross	14	Sacramento	74
Fresno	62	Salinas	56
Georgetown	30	San Bernardino	73
Healdsburg	15	San Diego	81
Hollister	57	San Francisco	39
Indio	77	San Jacinto	76
Jolon	59	San Jose	52
Julian	79	San Luis Obispo	61
Kennedy Mine	46	San Miguel Island	68
Kentfield	37	Santa Barbara	67
Kernville	65	Santa Clara	53
King City	58	Santa Cruz	55
Knights Landing	18	Santa Monica	69
Lake Spaulding	24	Santa Rosa	16
La Porte	21	Sisson	3
Lick Observatory	51	Sonora	48
Livermore	42	Sterling	82
Los Angeles	70	Stockton	43
Los Gatos	54	Summit	27
Marysville	19	Truckee	22
Merced	49	Tustin	71
Milton	44	Ukiah	13
Mokelumne Hill	45	Upper Mattole	5
Needles	78	Visalia	73
Nevada City	26	Westpoint	47
Newman	50	Willows	12
North Bloomfield	25	Yreka	1

NUMERICAL LIST

Yreka	1	Livermore	42
Cedarville	2	Stockton	43
Sisson	3	Milton	44
Eureka	4	Mokelumne Hill	45
Upper Mattole	5	Kennedy Mine	46
Redding	6	Westpoint	47
Red Bluff	7	Sonora	48
Quincy	8	Merced	49
Chico	9	Newman	50
Durham	10	Lick Observatory	51
Orland	11	San Jose	52
Willows	12	Santa Clara	53
Ukiah	13	Los Gatos	54
Fort Ross	14	Santa Cruz	55
Healdsburg	15	Salinas	56
Santa Rosa	16	Hollister	57
Davis	17	King City	58
Knights Landing	18	Jolon	59
Marysville	19	Paso Robles	60
Oroville	20	San Luis Obispo	61
La Porte	21	Fresno	62
Truckee	22	Visalia	63
Fordyce Dam	23	Porterville	64
Lake Spaulding	24	Kernville	65
North Bloomfield	25	Bakersfield	66
Nevada City	26	Santa Barbara	67
Summit	27	San Miguel Island	68
Colfax	28	Santa Monica	69
Auburn	29	Los Angeles	70
Georgetown	30	Tustin	71
Placerville	31	Claremont	72
Represa	32	San Bernardino	73
Folsom	33	Redlands	74
Sacramento	34	Riverside	75
Rio Vista	35	San Jacinto	76
Antioch	36	Indio	77
Kentfield	37	Needles	78
Point Reyes	38	Julian	79
San Francisco	39	Cuyamaca	80
Berkeley	40	San Diego	81
Oakland	41	Sterling	82

There are great areas in the Coast Ranges, notably in the north and in the south, that are unrepresented by any station. The Sierra above 4,000 feet is but poorly represented. The semi-arid and desert regions of the northeast and the southeast have very few stations with records of 25 seasons. The northeastern area has few records of whatever length. The southeastern area,

while poor in long-period stations, has of late years in the irrigated sections received a rapid increase in agricultural population, which has led to the establishment of a considerable number of stations, some of which had, at the close of the season 1919–20, 10 seasons of record and many of which had records of 5 to 10 seasons. We come then at once to the matter of the relations of topography in California to the selection of stations.

It is axiomatic in studies of this sort that the validity of the adjustment of short records by reference to long depends upon the topography of the area as related to the exposure of the stations involved. A plain such as the Great Valley of California is ideal in this respect, on account of the absence of surface features which would tend to interrupt the uniformity of control exerted by

FIG. 1.—Distribution of rainfall stations having 25 seasons or more of record ending 1919–20. (Numbers for identification of stations will be found in Table 3.)

the winds under the influence of cyclonic and anticyclonic circulations. But where the relief is broken the adjustment becomes untrustworthy unless careful regard be paid to the exposure of the stations. Hann[14] long ago pointed out the necessity, especially in the case of mountainous regions, of comparing stations with similar exposures; that is, of comparing windward slopes with windward slopes and leeward with leeward. It is clear that in an area with as strong relief as has California, where often the location of a town was determined solely by the location of gold, rainfall records have been made under widely diverse topographic conditions. Hence it is not possible to find ideal relations like those in the valley, and to that extent the results of the adjustments are open to question. Nevertheless, it is believed the evils arising from this source are less than those which would result from leaving the records unadjusted. The adjustment has been done, so far as might be, by choosing stations at the same general altitude as close together as possible, and having as great similarity in the larger features of the surrounding topography as proved feasible in the circumstances. There are, moreover, certain cases, in the mountain areas where adjustment has not been thought desirable. These are cases where a station had a record within one to five seasons of the full period (there is one case of 10 seasons), but where topography and distance from a long-period station suggested that probably the chance of error through reduction would be greater than that due to the use of the slightly shorter period. Fortunately a great many of the Sierra stations are in the long-period group, as previously stated, hence the number of cases in which adjustment was necessary was materially reduced.

The desert areas present somewhat different problems. Rainfall is there largely of the local, convectional type, and, though it tends to some extent to recur over regions especially favorable to this type of precipitation, nevertheless it is "spotty," highly variable in point of time and place, often of the thunderstorm cloudburst type. At certain desert stations the rainfall of one season has frequently been 500 to over 1,000 per cent of that of the preceding or following seasons.[15] At some stations in some seasons no measurable rain has fallen, while close to 10 inches has fallen at the same station in other seasons.[16] Topography is broken, alternating between steep, high mountain ranges, and flat intermont lowlands. Rainfall stations are far apart. Under these circumstances the results of adjustment to uniform period would in general be fictitious and illusory. There are a few cases in which adjustment has been made.

The question of what minimum length of record should be used was determined by the factors of closeness of station net and the location of short-period stations with reference to long, and above all, by the necessity just noted of leaving the records of many isolated desert stations unadjusted, thereby requiring that as great a minimum length as possible be used. The period finally decided upon was 10 seasons. How great is the probable error of means based on records as short as this has already been suggested; it is obviously undesirable to include stations with less than 10 seasons, while to hold to a higher minimum would so deplete the supply of available stations as to render the mapping of the desert rainfall even more uncertain than it is at present.

An inspection of Table 8 at the end of part 1 of this paper will indicate the relations of the means of rainfall as derived from the full length of record of each station to that derived from a 25-season period and to the averages derived by adjusting short records to long records where that has been necessary.

III. THE NEW RAINFALL MAP: PROBLEMS INVOLVED IN ITS CONSTRUCTION

1. General relations of the trend of mountain ranges to rain-bearing winds in California.—It has often been pointed out that California is a region of climatic extremes in the sense that almost every variety of climate to be found in North America is represented somewhere in the State. Fundamental to this condition are the

[14] Ibid., p. 114-115.

[15] E. g., Bagdad, Greenland Ranch, Imperial, Needles, Palm Springs, Salton, Sterling.

[16] E. g., Bagdad, Palm Springs.

great latitudinal extent of California, its position astride of the transition zone where "prevailing westerlies" alternate annually with "horse latitudes" in controlling the character of the seasons, its striking contrasts in relief, and the relations of the prevailing winds to the topography. In the drawing of a rainfall map of California the last two points have always to be kept in mind; for the directions of the *rainy* winds, fundamentally controlled by the pressure distribution in passing cyclones but modified by the configuration of the land, are so largely confined to the southern quarter of the compass that throughout much of the State there is a clear distinction between the amounts of rainfall on the windward and leeward slopes of the mountain ranges. The result is that where rainfall stations with adequate records are scarce, and where consequently the positions of isohyets must be inferred, the trend of the ranges with respect to the prevailing direction of the rainy wind becomes of great importance. In general, where such winds have certain dominant directions, the more nearly parallel is the mountain range to these directions, the more even will be the distribution of rainfall on the two sides of the range. In California none of the major ranges is so parallel; their angles to the wind vary from some 20 to 30° to right angles, with the resulting regional contrasts in precipitation just mentioned. Thus it is that the south, southwest, and west faces of the mountains are the rainy ones, and the north, northeast, and east the relatively dry. To the same control the valleys, shut off from the sea by mountain ranges, owe their dryness. These statements do not apply with equal force to the desert areas of the State, where the local convectional type of much of the precipitation probably tends toward a more even distribution of it about the mountain masses than is possible under more intense cyclonic control.

2. Changes in the amount of precipitation with altitude.—Furthermore, inferences regarding the amounts of rainfall taken in cross section from valley over crest to valley for areas where there are no stations must be based on the assumption that rainfall here, as elsewhere, shows an increase from a minimum at the windward base up to a certain elevation on the windward slope, above that a decrease to the crest line, and thence downward on the leeward slope a still more rapid decrease into the rain shadow at the base. The only region of California for which we have fairly adequate data on which to base conclusions in regard to changes in the amount of rainfall with altitude is the western flank of the Sierra. Even here the only chain of stations which can be considered first class in this respect is that extending from Sacramento on the west to Reno, Nev., on the east, along the Southern Pacific Railroad via the pass at Summit.

Data showing rainfall conditions for this chain, which have been published at various times,[17] using various lengths of record, all agree in showing that the zone of maximum precipitation occurs at about 5,000 feet elevation in this part of the Sierra. The rate of increase up to the zone of maximum has been variously stated. Lee,[18] as the results of investigations carried on for the Los Angeles Aqueduct Commission, in 1911 gave the average rate as 8.5 inches per 1,000 feet increase of elevation. McAdie [19] in 1914 gave it as about 9.15 inches per 1,000 feet. The present writer in 1920, in a study of the monthly variations of the precipitation-altitude relation in the central Sierra Nevada of California,[20] based on a uniform period of 20 years for the stations of this group, found a rate of 10.7 inches per 1,000 feet.

The point was emphasized that the rate of increase is most rapid in the lowest part of the section and decreases gradually with approach to the zone of maximum precipitation where it passes into the decrease above this zone.

The mean rate of decrease of precipitation from the zone of maximum up to the summit was found by the writer to be 8.8 inches per 1,000 feet and the rate of decrease from summit to base station on the leeward side 16 inches per 1,000 feet. This latter figure corresponds to that determined by Lee for this section as 17.4 inches per 1,000 feet of decrease in elevation above the 5,000-foot contour. Below this level the rate decreases. It is important to note that Lee found the rate for this central Sierra region to be not characteristic of the east slope of the range as a whole.[21] There is a progressive falling off in the rate of decrease as one goes southeast along the range; so that for the "Mokelumne section" (lying along a line drawn between Stockton, Calif., and Carson Lake, Nev.) it is 14.3 inches per 1,000 feet; for the "Taboose and Oak sections" (the Oak being in the latitude of Independence, Calif., and the Taboose 12 miles farther north), 4.6 inches; and for the "Bairs section" (12 to 15 miles north of Owens Lake), only 3.4 inches. These rates by Lee are based on computed rainfalls for the crest of the range, which are in turn based on measured stream discharge on both west and east slopes. The decrease in rate with decrease in latitude corresponds to the decrease in precipitation southward along the range.

Table 4.—*Monthly means of the 5 a. m. and 5. p. m. vapor pressures (in inches of mercury) at the pairs of stations—Fresno-San Diego and Sacramento-San Francisco*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Fresno	295	267	277. 5	266. 5	269	264. 4	275. 5	286. 5	287. 5	286	269. 5	238. 5
San Diego	296	314	331. 5	350	390	443. 5	510. 5	530. 5	495. 5	424	347. 5	280
Sacramento	265	284. 5	289	299	332	368. 5	400	393. 5	354. 5	319	292	250
San Francisco	288. 5	300. 5	297	306	327. 5	351	375. 5	389. 5	388. 5	363. 5	330. 5	282

3. Altitude of the zone of maximum rainfall.—With these changes according to latitude goes an increase in altitude of the zone of maximum rainfall with decreasing latitude in California. This seems to be due to the greater initial depression of the dew point of the air composing the rising currents in the southern Sierra, compared with that in the central and northern. This condition is due in turn to changes which take place in the relations between the absolute moisture content and the temperature of the air during its passage from the sea to the Interior Valley, from which it is drawn across the Sierra. Table 4 and Figure 2 show the monthly means of the 5 a. m. and 5 p. m. vapor pressures [22] at two pairs of stations, in connection with which the vapor pressure will be discussed. San Diego and Fresno have been chosen for illustration with reference to the southern Sierra (these being the two stations for which detailed data on vapor pressures are available); San Francisco and Sacramento with refer-

[17] Lee, C. H., Precipitation and altitude in the Sierra. Mo. Weather Rev., 1911 July, **39**: 1092–1099.
McAdie, Alexander, The rainfall of California. Univ. Calif. Publ. Geog., 1914, **1**: 127–140.
Henry, A. J., Increase of Precipitation with altitude. Mo. Weather Rev., 1919, January, **47**: 33–41. This paper contains numerous references to the literature of the subject.
[18] Lee, *loc. cit.*, 1099.
[19] McAdie, *loc. cit.*

[20] Varney, B. M., Monthly variations of the precipitation-altitude relation in the Central Sierra Nevada of California. Mo. Weather Rev., 1920, November, **48**: 648–650.
[21] Lee, *loc. cit.*
[22] Day, Preston C., Relative Humidities and Vapor Pressures over the United States, including a Discussion of Data from Recording Hair Hygrometers.
Mo. Weather Rev., Suppl. No. 6, May 7, 1917, Table 8.

ence to the northern, each pair thus including a coastal and an Interior Valley station.

In connection with the San Diego-Fresno pair inspection of the curves emphasizes the following outstanding facts: First, that in every month the vapor pressure is higher at San Diego than at Fresno; second, that the spread between their respective vapor pressures increases rapidly from a minimum in January (normally the rainiest month of the season) to a maximum in August in the heart of the dry season. It is the spread of the values during the rainy season that is most significant in connection with the altitude of the belt of maximum rainfall in the Sierra. For the San Francisco-Sacramento pair also the curves indicate that for the months of September to April, inclusive, or virtually the whole of the rainy season, the coastal station has a considerably higher vapor pressure than the interior station. That this is not the case for the months of May to August, inclusive, as shown by the curves, is not of much significance in view of the occurrence of by far the larger part of the season's precipitation in the remaining months.

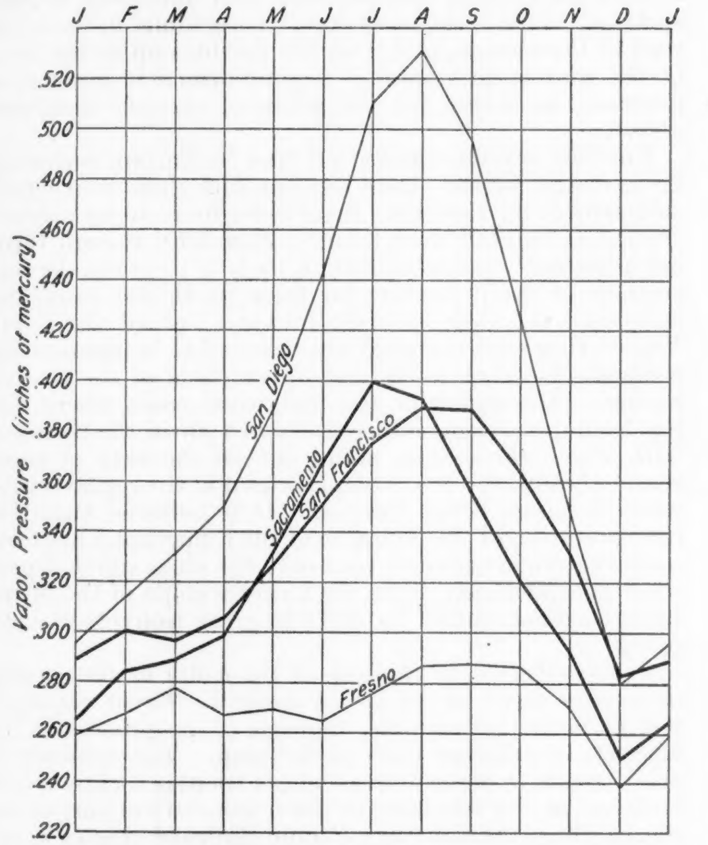

FIG. 2.—Monthly means of the 5 a. m. and 5 p. m. vapor pressures (in inches of mercury at the pairs of stations: San Diego and Fresno, San Francisco and Sacramento)

Comparing now the two sets of stations for the rainy season, it is seen that the spread between the coastal and the interior vapor-pressure values for all the included months is much greater for the case of the southern set than for the northern, which is to say that during the passage inland of the moisture-bearing south and southwest winds (which, being the prevailing winds of the rainy season, largely determine the vapor-pressure conditions) the air most likely to affect the southern pair of stations arrives in the valley considerably drier in the absolute sense than that of the north; and this in spite of the fact that the air from the sea off San Diego is much moister (absolutely) than that off San Francisco. In other words, so far as the moisture percentage of the atmosphere close to the earth's surface is concerned, the moister air of the two becomes the drier.

This change in the relations is due to two causes: First, the central and northern Sierra receives, at least in part, air which has come directly from the sea through a distinct low gap in the Coast Ranges (the actual break at San Francisco being too small to be of much significance in the total volume of air which passes inland through the gap), while the rain-bearing winds on the southern Sierra have crossed a great mountain region containing several ranges of the order of 5,000 feet altitude, and have therefore lost much more of their moisture in the process than do the winds which flow toward the central and northern Sierra; second, a certain amount of local convectional mixing takes place over the Great Valley even during the season of cyclonic storms. This is probably at a minimum during those storms which are intense enough to cause a cloud cover over valley and mountain alike. During the periods between storms, however, and during those storms which are only of sufficient intensity to cause a cloud cover over the mountains, convection over the valley is active, and therefore an efficient mixer of the lower several thousand feet of the atmosphere, and hence a factor in reducing the absolute moisture content of the air near the ground.

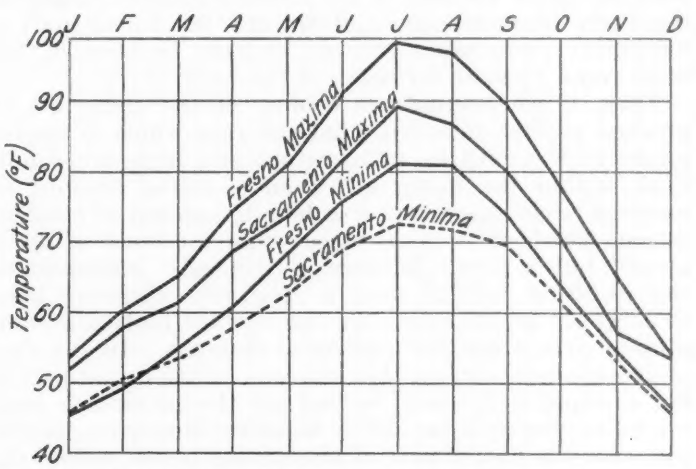

FIG. 3.—Annual march of the monthly mean temperatures and the monthly mean maximum temperatures at Fresno and Sacramento

It is obvious that, given a certain water-vapor content in a unit volume of air, the higher the temperature of the air the greater is the cooling necessary to cause condensation. As shown by the curves of Figure 3, in which the monthly mean temperatures and monthly mean maximum temperatures for Fresno and for Sacramento are plotted, both of these temperatures are somewhat higher for all months at Fresno than at Sacramento, except for the January and February minima. On this basis alone, then, the depression of the dew point would be greater at Fresno than at Sacramento. But the moisture content in the rainy season also has been shown to be lower at Fresno. Clearly, then, both temperature and moisture conditions greatly favor the production of the lower depression of the dew point in the region of Fresno. Hence air in passing up the slope of the Sierra from this region must rise considerably higher to reach the level of cloud formation, and therefore the level of the maximum rainfall occurs higher on that part of the Sierra than it does farther north.

It is unfortunate that there is no observational basis for determining changes in the precipitation-altitude

relation in the vast area of the Coast Ranges and the mountains of northern California. All that can safely be said is that most of these mountain masses probably lie below the level of maximum rainfall except those on the northern coast in the region of very heavy precipitation where the slopes are fully exposed to air blowing directly in from the sea. This point will be discussed in another connection. Such vertical distributions of stations as we have enable us only crudely to approximate the rate of increase of precipitation with altitude. Hence, satisfactory mapping of these important regions can not be done.

4. Form of transverse profile of mountain ranges as affecting the vertical and horizontal distribution of rainfall.—It has been shown that the shape and steepness of a slope are more important than differences of elevation alone in determining the amount of rainfall upon it at a given height.[23] If we assume that the water vapor in a body of air is so near saturation that further rise of the air will cause condensation, then, given a certain difference of elevation between base of slope and level of maximum rainfall and a certain horizontal distance between these limits, a strongly concave slope tends to cause a slower rate of increase over its lower part than over its higher because of the relatively slight raising of the body of moist air, and toward the upper part a somewhat more rapid rate of increase because of the more rapid upward thrusting of the body of air.

Thus, if we assume the cooling of the rising air to proceed at that retarded adiabatic rate which is appropriate to the existing temperature and moisture conditions within the rising air, then a stated amount of increase in elevation causes a definite amount of condensation, which, if it takes place while the body of air is moved but a short distance horizontally, concentrates the resulting rainfall over a relatively narrower zone than would be the case were the upward motion accomplished over a greater horizontal distance. In the case of the concave section this increase in the upper part is not as rapid as it would be had not the air already been forced to give up a part of its moisture during its gradual rise over the flatter part of the section below, where the fact that the air is there wetter, in an absolute sense, than in any other part of the section, results in even a moderate cooling, being the cause of considerable precipitation. The tendency for the case of the concave slope is therefore toward equalizing the rate of increase of precipitation with altitude.

Not so in the case of the convex section. Here the steepest slope is in the lower part of it. Over this part the air is warmer and contains more water vapor than over any other part of the section. It is therefore capable here of yielding a larger amount of precipitation for a given amount of cooling than in any other part. This cooling takes place through a shorter horizontal distance here than over any other part. The results are that precipitation over the lower part of the convex section is heavier than over the lower part of the concave, that by far the most rapid rate of increase in rainfall takes place over this lower part, and that the consequent removal of a large part of the moisture from the ascending current greatly reduces the rate of increase of rainfall in the upper part of the section. It is conceivable that the last-named condition may become so extreme that locally the level of maximum rainfall may occur over or slightly up the slope from the steepest part, making possible only a reduction of rainfall from there to the crest of the range. In other words, the zone of maximum precipitation would in such a case be warped downward toward the base of the range.

The relations of these matters to the topography of the Sierra are as follows: In general, the long western slope of the range, though cut by deep canyons, presents to the rain-bearing winds a surface little broken into distinct ranges except locally along its lower part. Moreover, considering the whole topographic profile below the level of maximum precipitation, there is no marked concavity, the whole region, exclusive of the canyons, forming an accordant "plateau" surface (using the term "plateau" not in its strict physiographic meaning) which declines toward the southwest.[24]

The rate of increase of rainfall therefore approximately follows the rule for such increase over uniformly sloping surfaces, namely, the most rapid rate is found in the lower part of the section, and it slowly declines up to the level of the maximum rainfall,[25] beyond which it becomes a decrease, as shown for the series of stations discussed above.

But this is undoubtedly not true for certain restricted areas in the Sierra. Here local profiles show convexities sufficient to indicate that there must be a strong concentration of rainfall over them. Therefore, though there are admittedly no precipitation records to prove the correctness of the procedure for these particular cases, the isohyets have been brought forward toward the Great Valley, thus showing what are believed to be appropriate contrasts between lower and upper parts of the rainfall section. Discussion of the individual cases where this has been done seems unnecessary in view of the clearness with which these areas stand out on the map of mean seasonal rainfall. An example is seen in the region southwest of Kings River Canyon. It is believed that this interpretation of the influence of the topography has been conservative in the sense that only the areas which depart most conspicuously from the uniform slope of the Sierra have been recognized by deflecting the isohyets as indicated.

5. Distribution of stations as the cause of the varying amount of detail shown by the isohyets.—Great contrasts will be noted between the amounts of irregularity in the isohyets in different parts of the map. The intricacy of their trends in certain areas where there is a close net of stations, as, for instance, in the north-central part of the Sierra where the Southern Pacific Railroad crosses it, indicates that the whole western slope would probably be similarly complicated if the details of the orographic control over precipitation were known. For the whole northern quarter of the State it may safely be said that the smoothness of the isohyets there shown effectually camouflages the detailed facts. This is an intricate mountain region of strong relief, very sparsely dotted with stations considered to have adequate records. The facts of local topographic influence are largely unknown. If known, they would probably result in making this part of the rainfall map as complicated as it is in the north-central Sierra region just mentioned.

6. Bases for inferring the amounts of precipitation above the level of observation.—It will be noted from the map that there are certain mountain areas standing boldly above the surrounding country, but without rainfall

[23] Pockels, F., The Theory of the Formation of Precipitation on Mountain Slopes. Smithsonian Mic. Coll. 51, No. 4, 80–104. This paper appeared originally in the Mo. WEATHER REV., April, 1901, 29: 152–9, and a supplementary note in the issue for July, 1901, 29: 306–307.

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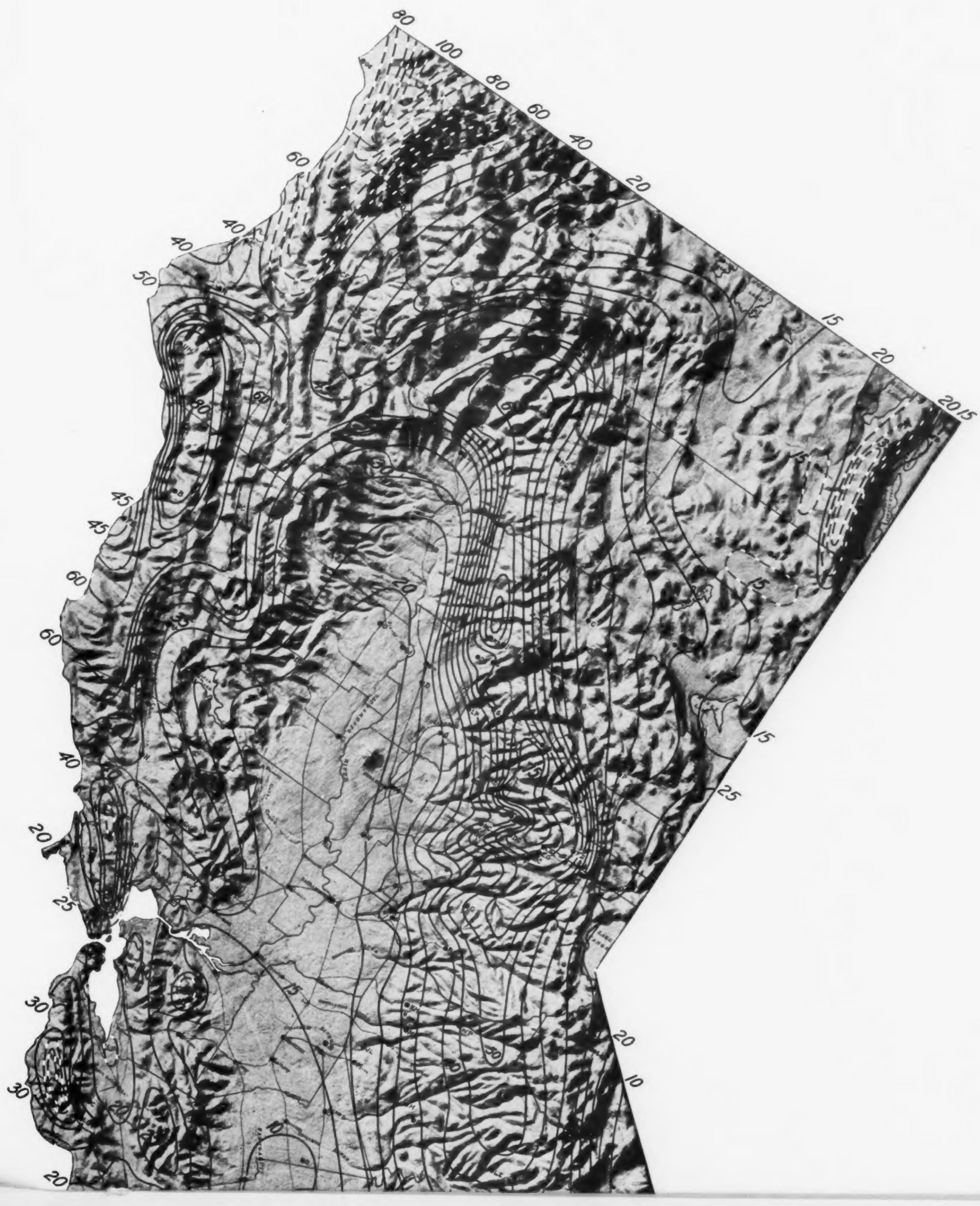
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relation in the vast area of the Coast Ranges and the mountains of northern California. All that can safely be said is that most of these mountain masses probably lie below the level of maximum rainfall except those on the northern coast in the region of very heavy precipitation where the slopes are fully exposed to air blowing directly in from the sea. This point will be discussed in another connection. Such vertical distributions of stations as we have enable us only crudely to approximate the rate of increase of precipitation with altitude. Hence, satisfactory mapping of these important regions can not be done.

4. Form of transverse profile of mountain ranges as affecting the vertical and horizontal distribution of rainfall.—It has been shown that the shape and steepness of a slope are more important than differences of elevation alone in determining the amount of rainfall upon it at a given height.[23] If we assume that the water vapor in a body of air is so near saturation that further rise of the air will cause condensation, then, given a certain difference of elevation between base of slope and level of maximum rainfall and a certain horizontal distance between these limits, a strongly concave slope tends to cause a slower rate of increase over its lower part than over its higher because of the relatively slight raising of the body of moist air, and toward the upper part a somewhat more rapid rate of increase because of the more rapid upward thrusting of the body of air.

Thus, if we assume the cooling of the rising air to proceed at that retarded adiabatic rate which is appropriate to the existing temperature and moisture conditions within the rising air, then a stated amount of increase in elevation causes a definite amount of condensation, which, if it takes place while the body of air is moved but a short distance horizontally, concentrates the resulting rainfall over a relatively narrower zone than would be the case were the upward motion accomplished over a greater horizontal distance. In the case of the concave section this increase in the upper part is not as rapid as it would be had not the air already been forced to give up a part of its moisture during its gradual rise over the flatter part of the section below, where the fact that the air is there wetter, in an absolute sense, than in any other part of the section, results in even a moderate cooling, being the cause of considerable precipitation. The tendency for the case of the concave slope is therefore toward equalizing the rate of increase of precipitation with altitude.

Not so in the case of the convex section. Here the steepest slope is in the lower part of it. Over this part the air is warmer and contains more water vapor than over any other part of the section. It is therefore capable here of yielding a larger amount of precipitation for a given amount of cooling than in any other part. This cooling takes place through a shorter horizontal distance here than over any other part. The results are that precipitation over the lower part of the convex section is heavier than over the lower part of the concave, that by far the most rapid rate of increase in rainfall takes place over this lower part, and that the consequent removal of a large part of the moisture from the ascending current greatly reduces the rate of increase of rainfall in the upper part of the section. It is conceivable that the last-named condition may become so extreme that locally the level of maximum rainfall may occur over or slightly up the slope from the steepest part, making possible only a reduction of rainfall from there to the crest of the range. In other words, the zone of maximum precipitation would in such a case be warped downward toward the base of the range.

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FIG. 4.—Average seasonal precipitation in California between July 1 and June 30. Isohyets are drawn for each 5-inch difference in rainfall and on the basis of records adjusted to a uniform period of 25 seasons, ending 1919–20. (The topographic base is reproduced from a photograph of the "Stanford Model.")

stations. Where their altitudes are of the order of five to ten thousand feet it would be inappropriate not to recognize this fact by the indication of a probable rainfall well in excess of that known for the surrounding country. An example of such mountain masses is the giant San Jacinto Peak in southern California, rising abruptly some ten thousand feet above the irrigated desert lowland on the east and eight to nine thousand feet above the orange orchards on the west. San Jacinto, permanently snow capped with the exception of two to four months of the year, is the scene of great thunderstorm activity and gives rise to permanent streams which water considerable irrigated tracts. Thus the San Jacinto River and its tributaries alone, constituting the main drainage system for the southwest side of the mountain, in 1918 supplied water for irrigating 9,015 acres.[26] It is evident that a considerable excess of precipitation over that of its surroundings falls upon such a massive peak and upon its attendant mountainous upland lying to the southeast. The problem is to estimate the amount of this precipitation as closely as possible. The following considerations are of importance.

6 (*a*). *Inferences from known rates of change in the amount of precipitation with altitude.*—Known rates of increase of precipitation with altitude furnish a reasonable basis for estimating the amounts of rainfall above the highest station of a given chain. The shorter, in terms of altitude, a chain of stations is, the less reliable are its indications as to the probable rainfall in the rest of the section involved. There are no chains of stations on San Jacinto. However, there are available for different sides of the mountain five rainfall records of varying lengths which give for a considerable range of altitude some idea of the conditions. The town of San Jacinto, lowest of the stations, 1,550 feet in altitude at the west base of the peak, has a 25-season rainfall mean (ending 1919–20) of 13.07 inches. From San Gorgonio Pass, on the northwest, at 2,560 feet, there is a broken record covering the years 1875 to 1888, showing a mean rainfall of 22.67 inches. Near Beaumont, also on the northwest, at 3,045 feet, a 10-year record from 1911 to 1921 shows a mean of 23.24 inches. Hurley Flat, at 3,500 feet, on the north side, had a mean of 21.49 inches for the two years 1919–1921. Idyllwild, at 5,250 feet altitude south of the peak, for the 10 years 1901–1911 averages 27.80 inches annually.[27] These features would appear to indicate that rainfall a little more than doubles in 3,700 feet of change up to the altitude of the highest station on San Jacinto.

Before pointing out the bearing of these figures on the problem of estimating the rainfall above this highest station it will be well to compare the conditions here with those elsewhere in southern California, which also throw light on the problem. Some 35 miles SSW. of San Jacinto Peak, Palomar Mountain, 6,126 feet in altitude, forms the culminating height of an upland for which there are rainfall records of various lengths, which, if reduced to a uniform 50-year period, indicate an increase with altitude as follows:[28]

Altitude	Precipitation
Feet	*Inches*
1,986	21.98
2,800	27.90
2,975	27.61
4,500	32.72
5,350	45.50

These figures would appear to indicate that rainfall a little more than doubles in 3,364 feet change of altitude up to the level of the highest station, which is to say that it increases in approximately the same proportions as on San Jacinto. It is important to note that here the highest station is vertically within 776 feet of the summit of the peak, while on San Jacinto it is 5,555 feet below the summit. Furthermore, both upper stations are below the level of maximum precipitation, as estimated by McAdie for southern California, 8,200 feet.[29] If for San Jacinto we may base a crude estimate of the rate of increase with altitude on the figures for the lowest and highest stations, these indicate that the rate averages approximately 0.40 inch per 100 feet. Assuming that this rate continues up to the altitude of the maximum rainfall, we have 39.60 inches as the precipitation at this level. The rate of increase probably declines, however, though it is impossible to say how rapidly, owing to the scattered location and varying exposures of the stations used in arriving at the estimate. It is believed that on this basis we may safely conclude that not less than 35 inches annually is the average precipitation at the zone of maximum on San Jacinto. It was hoped that a comparison of the vegetative cover on San Jacinto *v.* for instance, that along the Southern Pacific Railway in the Sierra, where the precipitation-altitude relation is pretty definitely known, might aid in estimating the amount of precipitation at the zone of maximum on San Jacinto. But it appears that in this case vegetation is no criterion. Thus the yellow pine which forms one of the major forest types, both on the Sierra and on San Jacinto, thrives under rainfalls ranging anywhere from about 10 inches annually to about 50 inches. Likewise the Douglas fir, of frequent occurrence in stands mixed with yellow pine, also characteristic of the two regions, lives under extremely diverse climatic conditions. Thus in the Puget Sound region it thrives on 100 inches of annual rainfall, and in the Rocky Mountains it is found where less than 15 inches occurs annually.[30] Neither of these trees, therefore, is useful as a precise rainfall indicator.

6 (*b*). *Inference from mean seasonal stream discharge.*—Draining the south and west sides of what may be called the San Jacinto Highland and the Palomar Highland (or, in other words, the sides exposed to the rain-bearing winds) are the San Jacinto and the San Luis Rey Rivers, respectively. Their two drainage areas cover 330 and 325 square miles, respectively. Estimates of the run-off above the main agricultural areas, based on stream discharges, show that for the San Jacinto basin this amounts to 2.76 inches annually and for the San Luis Rey 3.42 inches.[31] With respect to the average rainfalls of the areas as computed on the basis of five records for each, these run-offs stand in the relation of 100 to 86, which is to say that the run-off on the San Jacinto watershed is somewhat greater in proportion to the computed rainfall than is that on the San Luis Rey. This difference seems too large to be due to difficulties in deducing rainfall from run-off. It is, moreover, probably not due to differences in the nature of the land surfaces as affecting the absorption and retention of water. Geologically the two regions are similar, both being made up of originally deep-seated rocks from which run-off is in general rapid. The variation in the vegetative cover according to altitude is much the same in both.[32] Chapparal largely mantles the

[26] Irrigation Requirements of California Lands, Bulletin 6 of Division of Engineering and Irrigation, Department of Public Works, Sacramento, Calif. See Table 8, "Use of Water as Measured on Various Systems," data from Fruitvale Water Company, San Jacinto, and from Lake Hemet Water Company, pp. 129–30.

[27] Ibid., Table 4.

[28] Ibid., Table 4.

[29] McAdie, The Rainfall of California, *loc. cit.*

[30] See Sudworth, George B., Forest Trees of the Pacific Slope, U. S. Dept. of Agriculture, Forest Service, unnumbered bulletin issued October 1, 1908, Government Printing Office, Washington.

[31] Flow in California Streams. Bulletin 5, Division of Engineering and Irrigation, Dept. of Public Works, Sacramento, Calif. San Jacinto River, Table 136. San Luis Rey River, Table 134.

[32] Information from MS. map of vegetative types, furnished by O. E. Baker, Bureau of Agricultural Economics, U. S. Dept. of Agriculture.

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slopes up to some 5,000 to 6,000 feet (though locally interrupted by yellow pine beginning at about 3,000 feet). Above the chapparal begins a yellow pine-Douglas fir zone, represented on Palomar by relatively unimportant stands of this type about the summit, and on the San Jacinto by a forest which extends to approximately 9,000 feet. Above this, again, spruce-fir forest occupies the gulches about the three peaks of which San Jacinto proper is the culminating one. It seems as if the run-off in favor of the San Jacinto area, that run-off being the greater in proportion to the computed rainfall, might be ascribed to the fact that while the drainage areas are of almost exactly the same size, and while the rainfall averages given above represent conditions over virtually the same range of altitudes in the two regions, the run-off in the case of San Jacinto Highland is derived partly from a surface extending some 4,500 feet higher than that which culminates in Palomar Mountain. This is in agreement with the figures based on the estimated rate of increase of precipitation with altitude in the region.

6 (c). *Inference from monthly distribution of seasonal run-off.*—Examination of the monthly distribution of the seasonal run-off in the San Jacinto and San Luis Rey Rivers discloses the fact that the San Jacinto has much the steadier flow, as shown by the following Table 5 based for the San Jacinto on data assembled by the Lake Hemet Water Co., and for the San Luis Rey on those of the United States Geological Survey.[33]

TABLE 5.—*Comparison of the monthly distribution of run-off in per cent of seasonal total, San Jacinto and San Luis Rey Rivers*

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
San Jacinto	2.5	2.1	1.6	1.9	2.2	3.9	9.6	17.5	22.0	16.2	14.5	6.0
San Luis Rey	1.0	0.8	0.2	0.7	0.9	2.6	33.9	16.6	24.3	9.7	6.9	2.4

It is evident that the differences shown are due to certain differences in the nature of the two watersheds. That of the San Luis Rey lies entirely below the level at which snow lasts for the major part of the year, with the result that the maximum run-off occurs in January, the month of maximum rainfall. There is even a secondary maximum of run-off in March in sympathy with a secondary maximum of rainfall in March. In the San Jacinto, snow storage and the forest cover above the level of the highest station so far equalize the flow that the maximum is delayed until March and then is but 22 per cent of the seasonal total. Most significant, however, is the fact that in spite of the influence of January rains below the temporary snow line on San Jacinto, which rains are then the heaviest of the year, just as on the San Luis Rey, nevertheless the January run-off in the San Jacinto is only 9.6 per cent of the total, while in the San Luis Rey it is 33.9 per cent. While this is not direct evidence that an increase of precipitation continues well above 5,000 feet on San Jacinto Peak, it strongly favors that assumption.

6 (d). *Actual v. effective precipitation as related to observed run-off.*—It should be borne in mind, also, that the rates of run-off, measured above the beginning of the main agricultural area, represent net results after a certain amount of the ground water supply has been permanently removed by the growth of vegetation, and after an evaporation from the earth's surface which is exceedingly active under the desert conditions of high temperature and great depression of the dewpoint. Though it is equally important to recognize that to some extent even at the high altitudes these desert conditions reduce the amount of precipitation that reaches the ground, nevertheless, tending to neutralize this effect is the fact that at times of heavy local thunderstorms or of general cyclonic rains on the peak, the presence of a cloud cover reduces the air temperature and hence also the rate of evaporation, while the precipitation itself is its own protection against extreme evaporation except on the edges of the rainfall area, because what evaporation there is from the falling rain or snow helps to maintain a high humidity within the passing storm. Thus, during the periods of storm, evaporation losses are far less than the moisture income. In the period between storms, on the other hand, evaporation losses are enormous. Strong winds, high sun, high temperature, low relative humidity, and low pressure conditions at high altitudes all have their effect. These losses affect not only surfaces wet from recently fallen rain and snow, but the previously acquired moisture as well, through evaporation from plant surfaces and from the packed snows of winter. Snow in the gulches near the summit has been estimated to lie 30 to 40 feet deep.[34] Thus an extremely heavy original catch of precipitation may be so discounted that the net result in measured stream discharge effectively conceals the truth about precipitation at the high altitudes.

These considerations would seem to indicate that an increase in precipitation on San Jacinto, from 27.80 inches at 5,250 feet to at least 35 inches at the level of the maximum may be regarded as a certainty. Indeed, there would seem to be strong probability that 40 to 45 inches is nearer the truth than 35. With reference to the drawing of the isohyets on San Jacinto, then, it may be said, in conclusion, that all the evidence points to the advisability of thus indicating the rainfall at the summit.

7. *Summary of the factors influencing the locations of the isohyets.*—To discuss all the details of the considerations which have led to the manner of drawing the isohyets in various mountain regions of the State is not practicable. They included the following items: (1) Known amounts of seasonal rainfall at stations about the base and any evidence they furnish as to increase of rainfall with altitude; (2) latitude, as affecting the precipitation in the region in which the mountain is located, rainfall *in general* increasing from south to north in middle latitudes over west coasts; (3) altitude and the bulk of the mountain mass as affecting the amount of obstruction offered to the prevailing rainy wind, and therefore as affecting the amount of precipitation; (4) the position and height of the mountain range with reference to the position and height of other ranges between it and the ocean which might cause a rain-shadow on the ranges in the lee in case their positions relative to the direction of the rain-bearing winds made that possible.

8. *Character of lines used in drawing the isohyets.*—It remains to point out the reasons for using a different character of line in different parts of the map. Solid lines are used wherever we have United States Weather Bureau data to establish the limiting amounts of precipitation for any area. Thus on mountain slopes solid lines are used to indicate the probable distribution of rainfall up to the highest station, whether there are stations between the highest and lowest or not. The most complete series, which therefore allows the drawing

[33] Tables 133 and 136 in Flow in California Streams, *loc. cit.*

[34] Information from O. E. Baker, Bureau of Agricultural Economics, U. S. Dept. of Agriculture, based on personal experience on the peak.

of the isohyets with the greatest assurance, is that along the Southern Pacific Railroad, as already noted. The other extreme may be illustrated by the isohyets on the low ranges just southeast of Cape Mendocino. Serving the north end of this area are two stations, some 20 miles apart. The base station has a rainfall of 44 inches plus; the upper station, in a valley at an elevation of but 244 feet above sea level, has 82 inches plus. The only other station in this mountain group is some 40 miles away, at 2,000 feet altitude, near the south end of the ranges. It has 84 inches plus. Solid lines have been drawn for the whole group. It may be noted that in this case the relative altitudes of the two last-mentioned stations form no guide to their relative rainfalls, the reason being that while the southern station has the heavy rainfall appropriate to the windward slope of a coast range in northern California, the northern station receives essentially the same amount because it stands close under the lee of an outer range of hills equally well exposed to southerly and southwesterly winds from the sea, the precipitation "spilling over" the crest of the range into the valley beyond.

An example of another sort of treatment is that shown by the isohyets in the tumbled mountain region of the northwestern corner of the State. Here, in an area larger than Massachusetts, only four United States Weather Bureau stations have unbroken records of 10 years or more, ending 1919–20; three more have broken or closed records antedating that season; while the total number of records from Federal, State, or private sources is but 10. Massachusetts, with a topography which, owing to the slight relief, has far less influence on the distribution of rainfall than has that of northwestern California, has 22 active stations but three of which are of less than 20 years' standing. For this California area solid and severely smoothed isohyets indicate the estimated distribution of rainfall up to 50 inches, there being but one station with more than that amount (54 inches plus). There is a broken record covering 30 years for the coast station of Crescent City, in the extreme northwestern corner, indicating a seasonal average there of 70 inches plus. Together with this heavy sea-level rainfall, the facts of the altitudes of the ranges (up to 5,000 feet but largely 1,500 to 3,000), their exposure to rain-bearing winds, and a five-year mean of rainfall of 109 inches plus at Monumental, close to the California-Oregon line, appear to justify the drawing of broken isohyets up to 100 inches.

The third condition under which the isohyets have been drawn is that illustrated by the case of San Jacinto Peak, already discussed, where there are no records of any sort above a certain level. Under this condition broken lines represent extrapolation to whatever extent is thought justifiable in the circumstances.

IV. THE NEW RAINFALL MAP: DISCUSSION

The general relations of rainfall to topography in California have been so often pointed out that it is unnecessary to do so here. The rainfall map itself shows these relations in a clear and striking manner. There are, however, some items of interest which should be alluded to for the purpose of emphasizing certain facts of the distribution which are important from the point of view of agriculture in the State.

1. *The axes of heaviest rainfall in the Sierra and of least rainfall in the Interior Valley.*—Note has often been made of the position of the axis of maximum rainfall at some 5,000 feet altitude on the west slope of the Sierra, and of the importance of this and of the snow above this level to irrigation interests in California. Between this zone of maximum receipt of precipitation and that of maximum use, agriculturally, which is the great Central Valley, lies a zone which is becoming yearly of greater importance to California, a zone where the raising of deciduous fruits is carried on with a minimum requirement of water for irrigation, the rainfalls being of the order of 30 to 35 inches, neither too little nor too much for successful fruit raising. Bright sunshine is abundant, but, because of the altitude (roughly 1,000 to 2,000 feet), the excessively high temperatures of summer found in the valley rarely extend into the zone of deciduous fruits. Winter cold is sufficient to maintain the normal cycle of tree growth and rest. Altogether, this zone owes its increasing significance to a highly favorable combination of factors, not the least of which is the particular regional distribution of rainfall found on the mountain slope of which it occupies a part.

Related directly to the distribution of rainfall on the Sierra is its distribution in the Interior Valley. If one will carefully trace the positions of the 10, 15, and 20 inch isohyets, the fact becomes clear that the increase of rainfall on the east side of the valley begins many miles west of the actual western limits of the Sierra foothills. This westward extension of the rainfall is least marked in the southeastern part of the San Joaquin Valley and gradually increases to a maximum in the region between Stockton and Marysville. The region referred to stands, relative to the inflow of moist air from the Pacific Ocean, opposite the lowest wide gap in the barrier of the Coast Ranges. This gap, together with the area of maximum extension westward of the Sierra influence and the area of heaviest participation on the Sierra itself, are all in alignment from southwest to northeast. Hence it is, in part, that the lowest section of the Sierra forces the heaviest precipitation—aided (to an extent not possible to measure) by the greater frequency with which barometric depressions cross this area with respect to that farther south.

Thus the zone of minimum rainfall in the valley is pushed far to the west of the axis of it, being displaced least in the southeastern end and most in the northwestern third. Supplementing this influence of the Sierra must be recognized the influence of the Coast Ranges in causing a rain shadow in their lee, as already discussed in another connection.

2. *The concentration of the heaviest precipitation on the Sierra Nevada in its northern third.*—The records of the rainfall stations in the Sierra indicate that it is erroneous to picture the precipitation in that region as decreasing gradually and somewhat uniformly southeastward along the range. As nearly as can be determined, a rather sharp distinction should be made between the average amounts of rainfall in the northwestern third (north of a belt including Placerville and the southern end of Lake Tahoe) and the southern two-thirds. Northwest of the belt the rainfalls are of the order of 70 to 80 inches or more; and southeast of it they decrease abruptly to approximately 50 inches, decreasing therefrom southeastward in spite of the increasing altitude of the range. The evidence is to the effect that the decrease is somewhat gradual down to the latitude of Owens Lake, south of which the rainfall drops off rapidly toward the very small rainfalls east of the southern end of the San Joaquin Valley.

3. *The rainfall of the Coast Ranges.*—Another general misconception regarding the distribution of rainfall latitudinally in California is that it declines gradually from the northwest corner of the State along the Coast Ranges to the Mexican line. It should therefore be pointed out, first, that the decline, if one considers coast stations, is far from regular and is even interrupted by pronounced increases; and, second, that for every major range along the outer coast there is observational evidence to show that the mean seasonal rainfall upon it is not less than 30 inches. On the first point the following list (Table 6) of coastal stations, arranged in order from north to south, shows the true conditions:

TABLE 6.—*Rainfall at coastal stations in California*

Station	Mean seasonal rainfall	Length of record
	Inches	*Seasons*
Crescent City	76.17	26
Eureka	44.90	30
Fort Bragg	40.17	17
Fort Ross	53.70	42
San Francisco	22.48	71
Santa Cruz	27.10	42
San Luis Obispo	20.92	51
Santa Barbara	18.66	53
Santa Monica	14.74	34
San Diego	9.70	70

The most striking irregularity is the sharp break in the general magnitude of the amounts between Fort Ross and San Francisco, the former representing the southern end of a zone of precipitation which may be described as ranging from moderate to heavy, according to the orographic control; while San Francisco stands at the northern end of a zone of moderate to light rainfall comprising the southern two-thirds of the coast.

The second type of irregularity is seen in the local increases of precipitation between Fort Bragg and Fort Ross and between San Francisco and Santa Cruz. For each there is an obvious reason in the local orographic control, since both Fort Ross and Santa Cruz stand at the windward foot of a range of mountains that offers pronounced obstruction to the prevailing rainy wind.

From this point it is but a step to the recognition of the fact that the outermost Coast Range, fronting directly on the sea and broken by greater or lesser gaps which afford free entrance of the winds to the interior, has a precipitation which varies, regionally, even more markedly than that of the coastal stations. Every major unit of this outer range is the site of a relatively heavy rainfall. Every gap separating these units is a region of smaller rainfall.

Furthermore, note should be made of the striking difference between the rainfalls of the outer and inner Coast Ranges. Broadly speaking, the inner have half as much as the outer, for they lack the altitude necessary to force much precipitation from a supply of moisture that has already been greatly depleted on crossing the outer ranges.

The longitudinal valleys within the Coast Ranges show contrasts in rainfall with their bordering mountains not less striking than those of the Sacramento-San Joaquin with reference to the Coast Ranges in general and the Sierra Nevada. Beginning at about latitude 39° and extending southeastward to about latitude 36°, a chain of major valleys lies northeast of the outer ranges, and in them the rainfall is of the order of 20 to 30 inches less than on the outer ranges. In them the forests of the outer ranges give way to the grass lands of the valleys, which display an increasingly semiarid appearance from northwest to southeast. Here the summer temperatures occasionally rival those of the Interior Valley. As far as appearances go, the Pacific Ocean might be a thousand miles away instead of the fifteen or twenty, which it actually is. The Salinas Valley, southernmost of the chain and most appropriately named, presents an aridity only less striking than that of the great southeastern deserts in California. Irrigation is the only hope of agriculture; strong, hot winds from the northwest and clouds of drifting dust are typical of its summer climate.

4. *Rainfall gradients in California.*—Taken as a whole, the State is one of steep rainfall gradients, as is a natural corollary of the strong contrasts in topography. Emphasis is usually laid on the steep gradient over the leeward slope of the Sierra Nevada, particularly along the escarpment which extends along much of its length. Pronounced as this gradient is on account of its great latitudinal extent and on account of its steepness, it is far exceeded in steepness by gradients in at least three other localities in the State, all of them on the *windward* sides of mountain ranges. Of these, one is on the Sierra Nevada, another on the Coast Ranges, and the third on the San Bernardino Range in southern California. Table 7 below gives the particulars and expresses the gradients in inches and hundredths of rainfall per horizontal mile.

TABLE 7.—*Steep rainfall gradients in California* [1]

From—				To—				Distance	Rainfall gradient
Station	Altitude	Seasonal record	Mean rainfall	Station	Altitude	Seasonal record	Mean rainfall		
	Feet		*Inches*		*Feet*		*Inches*	*Miles*	*Inches per mile*
La Porte	*5,000*	*25*	*78.58*	*Truckee*	*5,819*	*25*	*24.61*	*49*	*1.10*
Chico	189	49	23.65	Inskip	4,975	13	78.31	24	2.28
Fort Bragg	74	17	40.17	Branscomb	2,000	17	86.54	20	2.31
Redlands	1,352	30	14.55	Squirrel Inn	5,280	16	38.96	12	2.03

[1] The data for a representative gradient in the region of decreasing precipitation east of the zone of maximum in the Sierra are italicized.

TABLE 8.—*Rainfall stations, lengths of records, seasonal rainfall averages, variabilities, departures, and probabilities, for California*

(Long-period stations in italics, with data in bold-face type.)

Station and county	Altitude of station above mean sea level	Number of seasons of record (total)	Average seasonal rainfall (inches) based on total number of seasons	Number of seasons used in deriving the averages based on uniform period (directly or by adjustment)	Average seasonal rainfall (inches) based either on uniform period or on the number of seasons used for adjustment to uniform period	Average seasonal rainfall based on uniform period (directly or by adjustment)	Station by which adjustment was made, where feasible	Average seasonal variability in percentage of average seasonal rainfall (based on number of seasons shown in column 5)	Average seasonal departures in percentage of average seasonal rainfall (based on number of seasons shown in column 5)	Average of seasonal departures above normal (derived as per column 9)	Average of seasonal departures below normal (derived as per column 9)	Percentage probabilities of plus and minus departures of stated amounts							
1	2	3	4	5	6	7	8	9	10	11	12	13							
												0-25		26-50		51-100		101	0
												+	−	+	−	+	−	+	
Aguanga (Riverside)	1,986	12	14.24	12	14.24	13.59	San Jacinto	31.4	21.5	25	18	25	42	8	17	8			
Alturas (Modoc)	4,460	15	12.34	15	12.34	13.04	Cedarville	19.9	19.5	22	17	26	46	13	7	0	0	0	7
Angiola (Tulare)	208	14	6.51	11	6.88	7.43	Visalia	37.6	24.0	22	26	37	18	9	27				
Antioch (Contra Costa)	46	41	12.51	25	12.44	12.44		37.7	29.5	32	27	16	24	32	20	0	8		
Arrowhead Springs (San Bernardino)	2,000	11	22.53	11	22.53	20.86	San Bernardino	25.7	22.0	20	24	37	27	9	18	9			
Auburn (Placer)	1,360	49	33.58	25	33.41	33.41		23.7	23.5	21	26	40	28	12	8	4	8		
Azusa (Los Angeles)	540	23	19.26				Not adjusted to uniform period.	42.7	32.0	29	35	26	4	22	32	4	4	0	4
Bagdad (San Bernardino)	784	17	2.19	17	2.19	1.77	Needles	105.2	85.0	100	70	17	6	6	17	41	12		
Bakersfield (Kern)	394	31	5.50	25	5.63	5.63		30.7	24.0	27	21	20	40	16	16	8			
Barstow (San Bernardino)	2,105	23	4.30	17	4.60		Not adjusted	49.8	34.5	32	37	18	16	12	12	24	12		
Berkeley (Alameda)	320	33	25.74	25	24.99	24.99		28.8	25.0	17	33	44	12	20	20	0	0	0	4
Bishop Creek (Inyo)	8,500	16	8.13	16	8.13		Not adjusted	34.7	60.5	68	53	6	0	13	19	19	37	6	
Blue Canyon (Placer)	4,695	21	65.63	21	65.63		do	30.0	27.0	34	20	10	43	14	14	10	0	0	10
Blythe (Riverside)	268	11	4.34	11	4.34		do	36.9	37.0	34	40	9	9	37	18	9	18		
Branscomb (Mendocino)	2,000	20	84.30	20	84.30	84.22	Ukiah	24.3	19.0	18	20	40	35	5	10	5	0	0	5
Brawley (Imperial)	105	9	2.45	9	2.45	2.21	Indio	62.9	46.5	62	31	11	33	11	11	11	11	11	
Calexico (Imperial)	0	15	2.82	15	2.82	2.41	Mecca	46.2	38.5	45	34	13	26	7	20	20	7	0	7
Caliente (Kern)	1,290	39	10.97	20	11.11		Not adjusted	25.2	27.5	26	29	35	10	10	35	5	0	0	5
Campbell (Santa Clara)	217	23	15.30	23	15.30	15.35	San Jose	45.7	30.5	32	29	18	30	26	13	4	9		
Campo (San Diego)	2,543	31	19.98	21	19.59		Not adjusted	32.0	24.0	25	23	28	33	10	14	10	5		
Camptonville (Yuba)	3,500	13	67.13	13	67.13	77.28	North Bloomfield	32.0	23.5	24	23	31	15	23	8				
Cedarville (Modoc)	4,675	26	13.15	25	13.31	13.31		25.7	19.0	21	17	28	44	16	12				
Chico (Butte)	189	49	23.63	25	24.77	24.77		24.9	19.5	20	19	36	36	8	16				
China Flat (Humboldt)	600	11	44.19	11	44.19	54.40	Eureka	19.3	17.0	17	17	37	27	9	18	0	0	0	9
Claremont (Los Angeles)	1,200	29	18.73	25	17.85	17.85		40.1	29.5	31	28	20	20	24	28	4	4		
Cloverdale (Sonoma)	340	20	41.75	18	40.32	40.35	Healdsburg	34.2	31.5	39	24	11	28	17	28	11	6		
Colfax (Placer)	2,421	50	47.72	25	49.83	49.83		29.8	23.0	20	26	28	16	24	20	0	4	0	8
Colusa (Colusa)	60	36	16.45	15	16.14	16.22	Marysville	35.4	26.0	21	31	40	13	13	20	7	7		
Cuyamaca (San Diego)	4,677	33	38.13	25	37.25	37.25		25.6	23.5	26	21	28	36	4	20	12			
Davis (Yolo)	51	48	17.03	25	17.02	17.02		36.8	28.5	28	29	24	24	24	24	4			
Deer Creek (Nevada)	3,700	13	67.37	13	67.37	77.51	North Bloomfield	32.1	24.0	26	22	23	31	23	23				
Denair (Stanislaus)	126	21	9.40	21	9.40	9.08	Merced	31.5	21.0	22	20	33	19	24	5	0	14	0	5
De Sabla (Butte)	2,500	16	66.31	16	66.31	64.45	Chico	34.7	24.0	24	24	25	25	25	25				
Dinuba (Tulare)	333	11	12.00	11	12.00	13.08	Visalia	21.4	15.5	14	17	46	36	9	9				
Dobbins (Yuba)	1,650	16	43.20	16	43.20	43.65	Nevada City	32.3	23.0	20	26	37	19	19	25				
Downieville (Sierra)	3,150	12	62.15	12	62.15	69.62	La Porte	29.6	21.0	21	21	25	25	25	25				
Durham (Butte)	160	25	24.60	25	24.60	24.60		23.2	20.0	19	21	36	24	16	24				
Edison (Kern)	2,500	16	11.19	16	11.19	10.19	Bakersfield	31.4	29.0	39	19	19	44	12	19	0	0	0	6
El Cajon (San Diego)	482	21	13.91	21	13.91	13.24	San Diego	29.8	25.5	29	22	24	38	10	14	5			
Electra (Amador)	725	16	32.52	16	32.52	35.81	Kennedy Mine	31.3	23.5	24	23	31	31	13	19	6			
Elsinore (Riverside)	1,234	21	13.32	20	13.03		Not adjusted	42.1	35.0	42	28	20	30	5	25	15	5		
Emigrant Gap (Placer)	5,230	40	53.01	15	56.32	57.54	Blue Canyon	28.6	26.0	30	22	27	27	0	27	13			
Escondido (San Diego)	650	23	16.18	23	16.18		Not adjusted	28.6	26.5	30	23	26	35	4	22	13			
Eureka (Humboldt)	64	30	46.56	25	41.21	41.21		20.8	19.5	23	16	20	52	16	8	4			
Folsom (Sacramento)	252	49	24.31	25	24.61	24.61		32.0	25.5	21	30	40	16	8	24	8	0	0	4
Fordyce Dam (Nevada)	6,500	26	68.55	25	66.63	66.63		25.2	19.5	22	17	28	40	12	16	4			
Fort Bidwell (Modoc)	4,640	27	22.16	9	13.25	20.47	Not adjusted (23 years)	21.1	11.0	12	10	38	56	11					
Fort Bragg (Mendocino)	74	20	37.97	16	38.83	40.53	Upper Mattole	28.3	22.0	20	24	31	31	19	12	0	0	0	6
Fort Ross (Sonoma)	100	45	53.21	25	54.63	54.63		24.2	21.5	22	21	28	32	20	20				
Fresno (Fresno)	293	42	9.80	25	9.30	9.30		27.5	21.0	20	22	36	32	16	16				
Georgetown (Eldorado)	2,650	47	57.04	25	55.53	55.53		31.8	24.0	26	22	20	28	24	0	0	0	0	4
Glennville (Kern)	2,500	11	20.36	11	20.36	20.10	Kernville	30.2	28.0	28	28	27	18	18	27				
Gold Run (Placer)	3,222	19	51.83	19	51.83	53.32	Colfax	33.6	21.0	22	20	32	37	16	16				
Grass Valley (Nevada)	2,090	45	52.75	12	52.34	55.55	Nevada City	32.2	24.5	29	20	17	33	25	25				
Greenland Ranch (Inyo)	−178	9	1.91	9	1.91		Not adjusted	66.7	48.5	43	54	22	11	11	11	22	22		
Hanford (King)	249	21	8.59	21	8.59	8.37	Visalia	26.8	18.5	19	18	38	38	10	14				
Head Dam (Yuba)	1,500	13	53.64	13	53.64	58.03	Nevada City	36.4	26.5	26	23	23	31	23	23				
Healdsburg (Sonoma)	52	43	41.52	25	40.76	40.76		31.3	28.5	32	25	12	24	28	28	4	4		
Helen Mine (Lake)	2,750	20	87.20	20	87.20	84.91	Ukiah	34.9	26.0	26	26	25	30	25	20				
Hollister (San Benito)	284	46	13.17	25	13.80	13.80		31.3	25.0	24	26	28	24	20	20	4	4		
Hullville (Lake)	2,250	13	49.55	13	49.55	52.40	Ukiah	34.8	25.0	27	23	23	31	15	23	8			
Independence (Inyo)	3,957	30	4.94	22	4.95		Not adjusted (22 years)	56.1	38.0	45	31	18	27	9	18	5	14	9	
Indio (Riverside)	−20	43	2.80	25	2.98	2.98		42.7	40.0	42	38	24	24	4	12	20	16		
Inskip (Butte)	4,975	13	78.31	13	78.31	79.51	Chico	35.1	24.0	26	22	31	31	8	23	8			
Jolon (Monterey)	960	38	16.46	25	16.98	16.98		42.1	32.5	38	27	8	28	24	20	8	8	0	4
Julian (San Diego)	4,500	21	33.18	11	32.51		Not adjusted					16	36	12	12	12	12		
Kennedy Mine (Amador)	1,500	28	32.87	25	31.14	41.14		25.4	23.0	26	20	28	28	16	28				
Kennet (Shasta)	730	13	61.31	13	61.31	64.71	Redding	34.7	35.5	49	22	8	38	0	31	23			
Kentfield (Marin)	65	32	48.41	25	47.25	47.25		31.3	23.0	21	25	32	20	20	24	0	0	0	4
Kernville (Kern)	2,600	26	10.37	25	10.19	10.19		49.6	32.5	39	26	20	32	8	24	8	4	4	
King City (Monterey)	333	33	11.04	25	11.06	11.06		44.4	35.0	42	28	16	32	12	16	12	12		
Knights Landing (Yolo)	41	30	17.94	25	17.87	17.87		33.2	24.5	24	25	32	20	12	28	8			
Lake Eleanor	4,700	10	39.45	10	39.45	42.38	Westpoint	29.0	24.0	24	24	30	30	20	20				
Lakeport (Lake)	1,450	19	29.55	19	29.55	28.67	Ukiah	33.2	28.5	33	24	16	32	16	21	11	5		
Lake Spaulding (Nevada) (about)	4,500	25	69.34	25	69.34	69.34		31.4	22.0	23	21	24	28	24	24				
La Porte (Plumas)	5,000	26	78.42	25	78.58	78.58		34.5	30.0	31	29	24	32	16	16	8	4		
Le Grand (Merced)	255	21	13.03	21	13.03	12.63	Merced	38.2	29.0	32	26	19	28	14	18	10	10		
Lemon Cove (Tulare)	600	21	15.38	21	15.38	15.06	Visalia	33.5	28.5	38	19	10	48	14	19	10			
Lick Observatory (Santa Clara)	4,209	42	30.26	25	28.35	28.35		27.3	18.5	18	19	36	32	12	16	4			
Livermore (Alameda)	485	49	17.39	25	14.83	14.83		36.0	26.0	27	25	24	24	20	28	4			
Lone Pine (Inyo)	3,728	16	5.70	16	5.70		Not adjusted	28.1	23.0	26	20	31	43	13	13				
Lordsburg (Los Angeles)	1,320	14	21.00	14	21.00	19.24	Sierra Madre	34.5	21.0	24	22	29	14	29	29				

TABLE 8.—*Rainfall stations, lengths of records, seasonal rainfall averages, variabilities, departures, and probabilities, for California*—Contd.

Station and county	Altitude of station above mean sea level	Number of seasons of record (total)	Average seasonal rainfall (inches) based on total number of seasons	Number of seasons used in deriving the averages based on uniform period (directly or by adjustment)	Average seasonal rainfall (inches) based either on uniform period or on the number of seasons used for adjustment to uniform period	Average seasonal rainfall based on uniform period (directly or by adjustment)	Station by which adjustment was made, where feasible	Average seasonal variability in percentage of average seasonal rainfall (based on number of seasons shown in column 5)	Average seasonal departures in percentage of average seasonal rainfall (based on number of seasons shown in column 5)	Average of seasonal departures above normal (derived as per column 9)	Average of seasonal departures below normal (derived as per column 9)	Percentage probabilities of plus and minus departures of stated amounts							
1	2	3	4	5	6	7	8	9	10	11	12	13							
												0–25		26–50		51–100		101	0
												+	−	+	−	+	−	+	
Los Alamos (Santa Barbara)	600	11	17.55	11	17.55	16.33	Santa Barbara	43.7	28.0	25	31	27	19	18	27	9	9		
Los Angeles (Los Angeles)	361	43	15.55	25	14.16	14.16		39.3	29.0	30	28	20	28	24	20	4	4		
Los Gatos (Santa Clara)	600	35	33.10	25	31.61	31.61		40.8	27.0	26	28	32	24	14	12	18	18	12	
Lytle Creek (San Bernardino)	2,250	15	38.44	15	38.44	34.21	San Bernardino	36.3	24.5	23	26	40	20	7	26	7			
Madeline (Lassen)	5,270	12	13.97	12	13.97	15.31	Cedarville	56.5	40.0	53	27	17	42	8	17	0	8	8	
Mariposa (Mariposa)	1,800	12	29.65	12	29.65	31.08	Westpoint	26.8	19.5	22	17	42	17	17	8				
Marysville (Yuba)	67	49	19.60	25	20.78	20.78		26.8	23.5	24	23	20	28	24	20	4	0	0	4
McCloud (Siskiyou)	3,270	9	45.08	9	45.08	55.19	Sisson	27.3	33.0	44	22	0	44	22	22	11			
Mecca (Riverside)	185	15	3.24	15	3.24	2.31	Indio	55.7	45.0	49	41	20	0	13	40	0	13	13	
Merced (Merced)	173	48	10.95	25	11.48	11.48		30.4	23.5	26	21	24	32	16	24	4			
Mesa Grande (San Diego)	3,350	12	30.85	12	30.85	29.80	Cuyamaca	21.7	23.0	24	18	25	42	8	17	8			
Mill Creek (Amador)	(?)	13	43.99	13	43.99	47.62	Westpoint	26.5	22.5	21	24	38	31	8	15	8			
Milo (Tulare)	1,600	22	22.24	22	22.24	21.36	Porterville	35.6	24.5	27	22	32	32	9	22	5			
Milton (Calaveras)	660	32	21.45	25	21.13	21.13		28.1	19.0	21	17	28	36	20	16				
Mojave (Kern)	2,751	37	4.93	19	4.42		Not adjusted	63.4	51.0	59	43	0	16	21	21	11	21	11	
Mokelumne Hill (Calaveras)	1,550	38	31.43	25	31.01	31.01		28.5	22.0	21	23	36	28	12	20	4			
Montague (Siskiyou)	2,450	29	12.14	17	13.24	12.71	Yreka	27.9	19.0	20	18	35	41	6	12	6			
Montgomery Creek (Shasta)	2,500	11	54.08	11	54.08	56.86	Redding	18.9	17.0	15	19	36	36	19	9				
Mount Tamalpais (Marin)	2,375	22	26.80	22	26.80	26.46	Kentfield	26.0	17.0	17	17	32	36	18	9	0	5		
Napa (Napa)	20	37	24.16	19	23.23		Not adjusted	29.3	20.5	17	24	37	11	21	26	0	0	0	5
Needles (San Bernardino)	477	28	4.21	25	4.44	4.44		67.1	56.0	65	47	8	20	4	8	34	28	4	4
Nellie (San Diego)	5,350	14	48.38	11	45.77	43.01	Escondido (23 years)	16.3	20.5	15	18	18	46	18	18				
Nevada City (Nevada)	2,580	56	53.77	25	49.60	49.60		29.5	22.5	20	25	36	20	20	24				
Newhall (Los Angeles)	1,200	38	17.88	20	17.94		Not adjusted	47.7	37.5	30	45	30	10	10	5	20	25		
Newman (Stanislaus)	91	31	10.84	25	10.33	10.33		32.8	27.5	29	26	24	20	16	32	8			
North Bloomfield (Nevada)	3,200	42	53.84	25	54.80	54.80		25.3	23.0	20	26	32	24	24	20				
North Fork (Madera)	3,000	12	35.70	12	35.70	35.49	Fresno	36.7	24.0	32	16	17	50	17	17				
Oakland (Alameda)	36	46	23.85	25	22.75	22.75		29.7	24.0	17	31	52	12	12	24				
Oceanside (San Diego)	60	10	12.86	10	12.86	12.13	Escondido (23 years)	31.0	26.5	32	21	20	40	10	20	10			
Ojai Valley (Ventura)	900	15	24.24	15	24.24	21.06	Santa Barbara	46.2	27.5	33	22	20	40	7	20	13			
Orland (Glenn)	254	37	17.93	25	18.32	18.32		32.7	27.5	31	24	32	8	16	12	8			
Orleans (Humboldt)	520	17	49.24	17	49.24	52.75	Eureka	31.4	17.0	15	19	47	29	0	12	6	0	0	6
Oroville (Butte)	250	36	27.05	25	27.86	27.86		24.8	22.0	19	25	44	24	12	20				
Ozena (Ventura)	3,680	16	17.32	16	17.32	14.76	Santa Barbara	31.0	35.0	35	27	13	25	25	31	6			
Parkfield (Monterey)	2,800	13	17.02	13	17.02	15.62	Paso Robles	43.9	38.5	53	24	0	23	8	38	23	8		
Pasadena (Los Angeles)	827	21	18.57	12	21.46	19.88	Sierra Madre (23 years)	30.2	22.0	27	17	33	50	0	8	8			
Paso Robles (San Luis Obispo)	800	33	16.40	25	16.27	16.27		38.2	28.5	32	25	16	32	20	20	8	4		
Peachland (Sonoma)	190	24	40.69	24	40.69	40.43	Santa Rosa	26.5	25.0	25	25	29	25	8	21	8	0	0	8
Placerville (Eldorado)	1,875	40	42.31	25	39.45	39.45		30.2	23.0	24	22	24	28	20	24	4			
Point Loma (San Diego)	302	16	11.42	16	11.42	10.22	San Diego	20.9	18.5	21	16	31	50	13	6				
Point Reyes (Marin)	490	37	21.04	25	19.78	19.78		27.0	25.0	24	26	28	24	24	20	0	4		
Porterville (Tulare)	464	31	10.20	25	10.42	10.42		26.9	22.0	21	23	40	28	8	20	4			
Priest Valley (Monterey)	2,240	22	20.70	22	20.70	20.01	Paso Robles	31.5	28.5	34	23	18	41	9	18	14			
Quincy (Plumas)	3,400	25	41.84	25	41.84	41.84		39.2	30.0	29	31	24	16	20	24	4	4	0	8
Red Bluff (Tehama)	307	43	25.13	25	24.28	24.28		29.1	24.0	24	24	20	28	28	16	0	4	0	4
Redding (Shasta)	552	45	38.33	25	38.98	38.98		27.7	24.0	25	23	28	40	12	8	8	4		
Redlands (San Bernardino)	1,352	31	14.67	25	13.95	13.95		36.7	28.0	26	30	28	16	16	24	8	4	0	4
Reedley (Fresno)	347	19	11.76	19	11.76	10.27	Fresno	25.6	23.0	24	22	26	26	16	26	5			
Represa (Sacramento)	[1]100	25	25.38	25	25.38	25.38		31.2	26.0	23	29	32	12	16	28	4	0	0	8
Rio Vista (Solano)	35	27	17.30	25	17.94	17.94		34.2	26.0	25	27	32	20	20	28				
Riverside (Riverside)	851	42	11.05	25	10.75	10.75		29.0	30.5	30	31	24	20	12	28	8	0	4	4
Rocklin (Placer)	249	47	21.96	18	24.02	23.70	Folsom	36.4	32.0	32	32	22	17	22	28	6	6		
Rhonerville (Humboldt)	75	19	42.88	19	42.88	44.51	Eureka	21.3	17.0	18	16	32	42	16	11				
Sacramento (Sacramento)	71	71	18.75	25	16.74	16.74		31.8	25.0	20	30	36	12	24	24	0	4		
Salinas (Monterey)	40	47	13.83	25	13.38	13.38		39.0	26.0	29	33	24	32	16	24	4			
San Bernardino (San Bernardino)	1,054	50	16.10	25	15.34	15.34		31.6	26.0	25	27	24	20	20	24	8	8		
San Diego (San Diego)	87	70	9.70	25	9.46	9.46		34.1	26.5	23	30	36	16	8	24	12	4		
San Francisco (San Francisco)	207	71	22.48	25	20.00	20.00		31.7	23.0	22	24	24	28	28	16	0	4		
San Jacinto (Riverside)	1,550	28	12.58	25	13.07	13.07		31.7	22.5	23	22	28	24	20	28				
San Jose (Santa Clara)	95	46	15.08	25	14.60	14.60		39.1	28.5	31	26	20	24	12	20	12	8		
San Luis Obispo (San Luis Obispo)	201	51	20.92	25	21.46	21.46		30.5	26.0	29	23	16	44	24	4	4	8		
San Miguel Island (Santa Barbara)	500	26	14.29	25	14.34	14.34		25.3	33.5	32	35	20	12	16	20	12	12	0	8
Santa Ana River (San Bernardino)	2,850	16	29.65	16	29.65	26.78	Redlands	23.5	25.0	25	25	25	25	19	31				
Santa Barbara (Santa Barbara)	130	53	18.66	25	19.68	19.68		41.5	32.0	35	29	20	20	8	28	16	4	0	4
Santa Clara (Santa Clara)	90	37	16.11	25	15.68	15.68		42.7	29.8	30	24	24	28	16	12	8	8	0	4
Santa Cruz (Santa Cruz)	20	42	24.72	25	27.14	27.14		31.7	24.0	23	25	32	24	12	16	8	8		
Santa Monica (Los Angeles)	110	35	14.99	25	14.52	14.52		35.8	28.0	27	29	24	20	28	24	0	4		
Santa Rosa (Sonoma)	181	32	31.15	25	29.30	29.30		25.5	22.5	22	23	32	28	12	12	4	4	0	8
Seven Oaks (San Bernardino)	5,000	10	28.73	10	28.73	27.06	Redlands	39.0	31.5	25	38	20	40	30	10				
Sierra Madre (Los Angeles)	1,400	23	24.24	23	24.24		Not adjusted	44.3	31.0	35	27	13	31	17	17	13	9		
Sierraville (Sierra)	5,000	11	23.51	11	23.51	24.63	Fordyce Dam	49.3	31.5	40	23	9	46	18	18	9			
Sisson (Siskiyou)	3,555	32	35.39	25	36.07	36.07		26.6	26.5	23	30	32	28	24	4	0	12		
Sonora (Tuolumne)	1,825	32	35.29	25	33.85	33.85		27.1	19.0	21	17	28	40	16	16				
Squirrel Inn (San Bernardino)	5,280	18	33.03	10	43.57	41.01	Redlands	40.4	33.0	44	22	10	40	10	20	10	0	0	10
Stanwood (Butte)	2,140	17	64.83	17	64.83	63.16	Chico	33.4	30.0	32	28	12	29	29	24	6			
Sterling (Imperial)	255	42	2.32	25	2.36	2.36		72.2	70.0	84	56	12	16	8	16	36	12		
St. Helena (Napa)	255	12	34.46	12	34.46	35.74	Santa Rosa	37.7	31.5	35	28	18	36	18	27	9			
Stockton (San Joaquin)	23	53	14.25	25	14.31	14.31		29.9	23.0	20	26	36	24	16	16	4	4		
Storey (Madera)	296	21	9.46	21	9.46	8.87	Fresno	26.9	21.0	21	21	28	28	14	19	5	0	0	5
Summit (Placer)	7,017	50	45.37	25	47.00	47.00		33.5	22.0	21	23	36	28	12	20	24			
Tahoe (Eldorado)	6,230	10	30.72	10	30.72	34.47	Truckee	42.2	25.0	25	25	30	40	20	10				
Tamarack (Alpine)	1,830	17	48.70	14	49.23	51.66	Westpoint	39.5	33.5	48	19	14	50	0	22	14			
Tehachapi (Kern)	3,964	37	10.69	19	9.38		Not adjusted	32.7	35.0	43	27	16	26	11	26	11	5	0	5
Tejon Rancho (Kern)	1,500	11	10.66	11	10.66	9.97	Bakersfield	24.2	20.5	22	19	36	46	9	9				

[1] About.

TABLE 8.—*Rainfall stations, lengths of records, seasonal rainfall averages, variabilities, departures, and probabilities, for California*—Contd.

Station and county	Altitude of station above mean sea level	Number of seasons of record (total)	Average seasonal rainfall (inches) based on total number of seasons	Number of seasons used in deriving the averages based on uniform period (directly of by adjustment)	Average seasonal rainfall (inches) based either on uniform period or on the number of seasons used for adjustment to uniform period	Average seasonal rainfall based on uniform period (directly or by adjustment)	Station by which adjustment was made, where feasible	Average seasonal variability in percentage of average seasonal rainfall (based on number of seasons shown in column 5)	Average seasonal departures in percentage of average seasonal rainfall (based on number of seasons shown in column 5)	Average of seasonal departures above normal (derived as per column 9)	Average of seasonal departures below normal (derived as per column 9)	Percentage probabilities of plus and minus departures of stated amounts							
1	2	3	4	5	6	7	8	9	10	11	12	13							
												0-25		26-50		51-100		101	0
												+	−	+	−	+	−	+	----
Three Rivers (Tulare)	870	11	19.53	11	19.53	21.27	Visalia	28.4	23.0	17	29	55	9	9	27	----	----	----	----
Truckee (Nevada)	**5,819**	**50**	**26.13**	**25**	**24.61**	**24.61**		**34.2**	**22.0**	**22**	**22**	**36**	**28**	**4**	**20**	**12**	----	----	----
Towle (Placer)	3,704	30	57.36	15	59.66	-------	Not adjusted	28.4	21.5	19	22	40	26	13	20	----	----	----	----
Tustin (Orange)	**200**	**43**	**13.15**	**25**	**12.30**	**12.30**		**34.3**	**30.0**	**31**	**29**	**16**	**20**	**20**	**28**	**12**	**4**	----	----
Ukiah (Mendocino)	**620**	**43**	**36.56**	**25**	**37.24**	**37.24**		**30.6**	**26.0**	**29**	**23**	**20**	**24**	**16**	**20**	**4**	**0**	**0**	**8**
Upland (San Bernardino)	1,750	20	21.00	16	20.44	17.95	San Bernardino	42.3	31.0	31	31	25	13	19	31	6	6	----	----
Vacaville (Solano)	175	21	25.88	21	25.88	25.48	Rio Vista	31.4	24.5	21	28	24	24	20	14	5	5	----	----
Valley Springs (Calaveras)	673	27	24.33	20	23.86	23.58	Mokelumne Hill	31.0	23.5	21	26	28	20	20	25	----	----	----	----
Ventura (Ventura)	50	35	15.94	11	13.46	12.53	Santa Barbara	38.9	30.5	28	27	27	18	9	27	9	9	----	----
Visalia (Tulare)	**334**	**41**	**9.80**	**25**	**9.41**	**9.41**		**26.1**	**19.0**	**18**	**20**	**36**	**32**	**16**	**16**	----	----	----	----
Warner Springs (San Diego)	3,165	14	18.09	14	18.09	17.14	Escondido	25.7	23.0	30	16	14	50	22	14	----	----	----	----
Wasco (Kern)	336	21	6.23	21	6.23	5.97	Bakersfield	35.4	37.5	49	26	14	28	10	33	0	0	10	5
Watsonville (Santa Cruz)	23	30	21.67	21	22.54	21.76	Santa Cruz	36.6	24.0	25	23	29	33	14	14	5	5	----	----
West Branch (Butte)	3,216	13	70.90	13	70.90	75.85	Chico	29.8	26.0	32	20	23	38	8	23	8	----	----	----
Westpoint (Calaveras)	**2,326**	**26**	**41.11**	**25**	**40.36**	**40.36**		**26.9**	**21.5**	**21**	**22**	**36**	**32**	**16**	**16**	----	----	----	----
Willows (Glenn)	**136**	**41**	**16.54**	**25**	**17.07**	**17.07**		**31.0**	**28.0**	**26**	**30**	**28**	**24**	**16**	**12**	**8**	**8**	**0**	**4**
Yosemite (Mariposa)	3,945	16	35.10	16	35.10	35.52	Westpoint	29.6	25.0	22	28	37	13	13	31	6	----	----	----
Yreka (Siskiyou)	**2,625**	**43**	**17.53**	**25**	**18.95**	**18.97**		**37.8**	**27.0**	**28**	**32**	**32**	**16**	**4**	**24**	**12**	**4**	**0**	**8**

NOTES, ABSTRACTS, AND REVIEWS

SEVENTY-FIFTH ANNIVERSARY OF THE ROYAL METEOROLOGICAL SOCIETY

Nature, for May 2, 1925, contains an account of the celebration of this event in London on April 21–22, 1925. The completion by the Royal Meteorological Society of 75 years of continuous and increasing service is an event in which meteorologists of whatever country may well take pride.

The founding of the British Meteorological Society on April 3, 1850, had been preceded by the somewhat checkered careers of two meteorological organizations. The first English Meteorological Society was begun in 1823, Luke Howard being one of the founders and apparently its chief inspiration, for the society died of inanition after Howard's removal from London. In 1836 the Meteorological Society of London came into being. Gradual encroachment of astrological tendencies in the new organization, however, led to the founding of the British Meteorological Society. James Glaisher was its guiding spirit in the early years. He was its secretary from 1850 for 22 years, except for two years during which he was its president. In 1866 the society was granted a royal charter, its members becoming fellows of the Meteorological Society. The organization in 1882 changed its name to Royal Meteorological Society by permission of Queen Victoria.

In conformity with the ideas expressed by [John] Ruskin, the society at first devoted itself to the expensive task of the collection and publication of meteorological observations from a number of stations, chiefly in England and Wales, as well as to the reading, discussion, and publication of original papers. For it will be recalled that in 1850 there was no State provision for meteorology in Great Britain. The results of this work are printed in the Meteorological Record, which was published annually from 1881 until 1910. In 1911 the work was transferred to the State service, the Meteorological Office. Many investigations were undertaken by the society in its corporate capacity and brought to a successful conclusion. Among these may be mentioned the collection of phenological observations from the area of the British Isles and the annual publication of a phenological report in the Quarterly Journal of the society. This enterprise is still vigorously pursued, the whole of the work of observation and compilation being voluntarily given. In 1919 the Scottish Meteorological Society, which had been founded in Edinburgh in 1855, was dissolved, and as many members of that society as so desired were received as fellows of the Royal Meteorological Society. * * *

The anniversary meeting on the afternoon of April 22 was the principal event in connection with the celebration. The president welcomed the four honorary members who were present, namely, Prof. W. van Bemmelen, lately director of the Batavia Observatory; Prof. E. van Everdingen; Prof. H. Hergesell, director of the Aerological Observatory at Lindenberg; and Prof. Th. Hesselberg, director of the Norwegian Meteorological Service and secretary of the International Meteorological Committee.

At this meeting congratulatory messages were read from King George, from foreign meteorological organizations, and from a number of private individuals, among them the venerable Prof. H. Hildebrandsson, now in his 87th year.

Professor van Everdingen delivered the principal address, "Clouds and forecasting weather." He urged the importance to the forecaster of having regularly available current information on cloud movement and on the extent of cloud sheets as affecting the horizontal extent of related temperature inversions and through them the probabilities of rain. He pointed out also the value of halo observations, and referred to the correlation, at de Bilt, Holland, between halo occurrences and subsequent rainfall. In 1922, 70 per cent of the cases of halo were followed by rain, and only 70 out of 200 rainy days were not preceded by halos somewhere in Holland.

Addresses at the anniversary dinner dealt with the aerological observations being carried on by the British Navy by means of pilot and sounding balloons; with events in the history of the society; with the aid rendered by meteorologists to the airship *R 33* in connection with her recent break away from the mooring mast at Pulham during a gale. Professor van Everdingen responded to Sir Napier Shaw's toast, "International meteorology."—*B. M. V.*

THE QUESTION OF "ABNORMALITIES"

By L. C. W. BONACINA

[27 Tanza Road, Hampstead, London, N. W. 3, England, April 14, 1925]

Having read with great interest Mr. Milham's article on the "Cause of abnormalties" in the December REVIEW, and while fully appreciating the potency of the various physical factors which he discusses in determining meteorological variations, may I beg the courtesy of your columns to raise a point of criticism in regard to the important matter of definition, that is to say, what we understand, or ought to understand, by the term "abnormality" as used in meteorology?

It seems to me a grave philosophical error, likely to blind us to the true nature of weather variations, to regard any given, more-or-less-pronounced, deviation as something, so to speak, detached from the less pronounced deviations, and in special need of explanation, in view of the fact which must be apparent to all meteorologists on reflection, namely, that the weather is always to some extent, and in particular ways, "abnormal." The weather in respect to its various elements is always either above or below that datum line which we call the normal or average, and most of the extreme swings of the pendulum differ merely in intensity, not in the order or magnitude, from the next widest deviations from the average.

There can be no harm in calling any departure from the average datum line an abnormality in a restricted, literal sense, provided the practice does not obscure a recognition of the fact that the continual oscillations above and below the average datum line are the ordinary normal contingencies of climate, are, in other words, "normal abnormalities." It is only if a departure from average occurred of an order of magnitude completely isolated from all other departures that the "abnormality" would be truly abnormal and worthy of special investigation. Let me give an illustration from the climate of my own country. During mild spells of weather in December or January in England the temperature will commonly be between 50° and 60° F. for several days together, and the humid warmth is a very characteristic type—a normal contingency to be expected at intervals every winter. Yet the type is commonly spoken of as "abnormally mild" because the temperature is so many degrees above the average datum line for the season, and the danger of the phrase lies in the almost unavoidable implication that such considerable departures from the mean or average are really very rare instead of being in actual fact ordinary experiences of climate. But if midwinter warmth in England were ever to reach such an unheard-of degree of intensity that the thermometer rose over a wide area for a considerable time between 60° and 70° F. then we should clearly be confronted with an abnormality in the real sense of the term, pointing to some extraneous influence upon climate.

The point that I would especially make is this: That if extreme swings of the climatic pendulum, the "record" events, merely differ in intensity and not in order of magnitude, from other of the rarer swings of the pendulum, they should not be thought of as something out of harmony with the ordinary run of weather. Precise intensities of weather are in a certain sense "accidental." A storm, for example, of record violence is of little moment from the purely meteorological point of view in comparison with the type to which it belongs.

In regard to the year 1816, which forms the basis of Mr. Milham's article, it becomes a question in what sense this year was "abnormal" in America, whether the difference from other cold summers was simply one of intensity or one of actual type and order of magnitude.

Discussion.—The objection of Mr. Bonacina has to do with the definition of the words "abnormal" and "abnormalities" as used in meteorology. When, for example, is a month abnormal in temperature? When is a temperature abnormality considered to exist?

According to the usual dictionary definition of abnormal, anything is considered abnormal when it departs from normal. If this definition of abnormal is adopted in meteorology then it follows of course *every* month is abnormal (to take a single element as an example) in temperature since every month departs from the average datum line. Our weather, then, consists of a ceaseless succession of abnormalities. When the departures from average are slight it is usually impossible to determine their physical causes and they also do not attract public attention.

If a departure from average is large, continues for a long time, and exists over a large area, it is sometimes possible to determine its physical causes. It, of course, attracts public attention. It would be desirable in some ways to reserve the word "abnormal" for such departures. But this would necessitate the setting up of a criterion in every case to determine how marked the departure must be to be considered abnormal, and this is practically impossible. It would also be artificial since departures from normal in meteorology are never of a different order of magnitude or produced by unusual causes. The record-breaking departure from average (the greatest abnormality) always differs but little from the next largest departure, etc. For example, the summer months of 1816 in the northeastern portion of the United States were but slightly colder than certain summer months during the following 20 years. There was no different order of magnitude and presumably there were no different physical causes.—*W. I. Milham.*

The above communications seem to be in essential agreement as to the impossibility of setting up universally applicable criteria for determining when a departure from the average should be called "abnormal." Perhaps, then to make the best of a bad situation, one may beg the question by inserting an adjective before "abnormality," such as *unusual*, or *rare*. This being done, we should be in a position to establish for a particular region and in the light of recorded experience in that region, what should be considered an unusual abnormality.

The occurrence of the very heavy rains on the desert west coast of South America early in 1925 is a case in point. Such rains have occurred in the past, and they will doubtless occur in the future. There is no evidence to show that they are due to anything more than an unusual intensification of causes which are in some degree operative every year. It becomes a matter of indicating whether or not such rains are, in view of meteorological experience in that particular region, unusually abnormal. That they are seems evident enough—but we haven't set up our criterion for the region.

There is essential agreement, also, on the view that, within human experience down to the present, "departures from normal in meteorology are never of a different order of magnitude or produced by unusual causes." This being the case, one sentence in Mr. Bonacina's note, *taken at its face value*, leads to an impli-

cation which he can hardly have had in mind: "It is only if a departure from average occurred of an order of magnitude completely isolated from all other departures that the 'abnormality' would be truly abnormal *and worthy of special investigation.*" [Italics mine.—B. M. V.] There have been occasional references of late, particularly in British meteorological publications, to the great desirability of including the dissection of individual depressions in our research into the structure of cyclones—of going into what some one has called micrometeorology. Few will disagree with this view. The consequences to meteorology would be serious indeed, were it generally maintained that departures from normal are unworthy of special investigation because they never exceed a certain order of magnitude and are never produced by unusual causes. It may be suggested that those cyclones which have brought about rare abnormalities are perhaps most worthy of special investigation, for the reason that they are striking examples of a type.—*B. M. Varney.*

THE LONDON FOG OF JANUARY 10–11, 1925

[Abstracted from Meteorological Magazine, February, 1925, pp. 7–9]

The heavy fog on the above date followed a month after the great fog of December, 1924. Mr. L. C. W. Bonacina, having made a very thorough series of observations in various parts of London on the occasion of the January fog, notes that two distinct types of "fog" occurred simultaneously, though singly or together according to locality. In the densely built-up streets of central London "the fog took the form of a dark, pungent, unsaturated haze, leaving pavements and clothes perfectly dry and causing little hindrance to traffic, the visibility being at least 50 yards." But in all open spaces, such as parks, squares, etc., the fog took the "form of great rolling blankets, very wetting and impenetrable to vision and completely paralyzing traffic."

The point is emphasized that a clearer distinction ought to be made between those fogs which should be regarded as smoke haze and the fog which is a combination of smoke haze and water droplets. It is the latter type which makes the serious trouble. The inference is drawn that if the smoke factor could be eliminated inner London would experience far less fog than suburban London and the more open country round about, where radiation fog so readily results from nocturnal radiation.

Discussing Mr. Bonacina's note, Mr. F. J. W. Whipple points out that the existence of the purely smoke haze in the densely built-up area may have been the result of the evaporation of water-fog particles on account of the warmth of pavements, air from buildings, etc. Great fogs attain a thickness of some 500 feet over London. Radiation cooling at the upper surface of the fog is believed to be intense enough to set up a convectional circulation between this upper surface and the ground and consequently to result in the constant bringing down of smoke particles, thus keeping the smoke haze black in the streets.

[It would be of interest to have comparative observations on the nature of the fog at street level in central London and on the highest buildings or towers in the same locality at the same time. Such observations might well show that above the smoke haze of the streets distance from sources of warmth permits the existence of the combination smoke haze and water fog of the same nature as that which is found at ground level in the parks and squares.]—*B. M. V.*

MEASUREMENT OF UPPER-WIND VELOCITIES BY OBSERVATIONS OF ARTIFICIAL CLOUDS

By C. D. Stewart

[Abstract accompanying B. M. O. Professional Notes, vol. 33, No. 38]

This paper gives the theory and practical details of the method of obtaining upper wind velocities from observations of clouds in a mirror. The apparent path of a cloud is traced on the surface of a Hill mirror, and from the length of the trace on the mirror the wind velocity at the height of the cloud is computed by simple multiplication by the use of a table of factors given in the text. The method was first used with shell bursts during the war, but the paper describes how it has been extended to include observations of clouds discharged from airplanes. Tables are given to enable the pilot to correct his height to the necessary degree for any readings of his altimeter and thermometer. The method is extremely simple in use.

WARM AND COLD WINTERS IN SIBERIA AND THEIR DEPENDENCE ON THE CONDITION OF THE GULF STREAM [1]

W. B. Schostakowitch, in Meteorologische Zeitschrift for January, 1925, presents a résumé of his studies on the above subject, including tables which recapitulate the most important results and statements of his conclusions as to the various relations between the Gulf stream and Siberian winter temperatures. The work was based on the records of 13 stations, and December, January, and February were taken as the winter months.

In 16 out of 22 winters temperature departures had the same sign throughout Siberia except along the borders. In one winter plus and minus departures were variously distributed; in two winters, eastern and western Siberia showed opposite departures; in three winters, central Siberia showed departures of the same sign throughout the area but opposite to the departures in the west.

Thirty years of record at Irkutsk show the anomalies of pressure and temperature to have had opposite signs in 73 per cent of the cases. In the average, negative pressure anomaly of 1 mm. coincided with a positive temperature anomaly of 0.98° C.; a positive pressure departure of 1 mm. coincided with a negative temperature departure of 1.1° C. A correlation coefficient of —0.646 with a probable error of —0.072 was found for the pressure-temperature relation.

Underdevelopment of the Siberian anticyclone, rather than displacement of it, is found to be characteristic of the winters with plus temperature anomaly, whereas in the cold winters the whole of Asiatic Russia is overlaid by abnormally high atmospheric pressure. The typical warm-winter pressure distribution favors invasion of central Siberia by cyclones from northwestern Europe,

[1] The following comment, questioning the appropriateness of the name "Gulf Stream," especially as applied to the waters adjacent to the northwest coast of Europe, is made by Mr. J. N. Nielson, of the Meteorological Institute of Copenhagen, in a note on the hydrography of the *Dana* Expedition (1921–22 in the Atlantic Ocean) printed in *Nature* for April 11, 1925, pp. 529–530. Mr. Nielsen's observation is of particular interest because it divides what is generally called in this country the North Atlantic drift into two parts with radically different characteristics. "In the waters south of Newfoundland the Florida current meets the Labrador current, giving rise to a mixed product with somewhat lower temperature and salinity than are found in the continuation of the Antille current, which runs on the right side of the Florida current and consists of water masses which keep outside the islands of the Antilles. * * *

"The mixed product arising from the Labrador and Florida currents fills the considerable area of sea south of Iceland, while the warm and salt water washing the coasts of northwest Europe is undoubtedly mainly derived from the Antille current. The term 'Gulf Stream', generally employed in European parlance to denote the warm current in the northeastern part of the Atlantic, must therefore be regarded as inappropriate, since it can only rightly apply to the current off the east coast of the United States, and even this would be better designated by the older name of "Florida current," as the current in question does not originate in the Gulf of Mexico, but comes from the equatorial region, and covers only the shortest possible distance in the Gulf of Mexico."

each cyclone being attended by a notable rise in temperature.

A closed cycle of changes in the distribution and sign of departures in air temperature, pressure, wind velocity, ocean current velocity, and coincident changes in the temperature of the Gulf stream and in air temperatures over northwestern Europe operates to maintain the *status quo* of one type of regime until some fundamental dynamical change brings a shift to another type.

The author cites three general conclusions of Meinardus relative to the effects of changes in the circulation in the northern North Atlantic Ocean, as follows:

At times of strengthened atmospheric circulation over that area, there result (*a*) a higher temperature of the Gulf stream [North Atlantic drift] along the European coast, (*b*) an amount of ice above normal on the Iceland coast, and (*c*) an amount of ice above normal on the Newfoundland coast, the Denmark-Iceland pressure gradient being used as an index to the atmospheric circulation. At times of weakened atmospheric circulation the reverse of these results is found.

The most striking relations of these and other conditions, to winter temperature in Siberia, are summarized as follows:

(1) Based on Petterson's determinations of conspicuous temperature departures of the Gulf stream along the coast of Norway:

Gulf stream warmer than normal		*Gulf stream colder than normal*	
Winter temperature anomaly in Siberia:	°*C.*	Winter temperature anomaly in Siberia:	°*C.*
1873–74	3.5	1874–75	−1.4
1881–82	3.2	1876–77	−2.0
1883–84	3.2	1878–79	−1.7
1886–87	2.1	1890–91	−0.7

(2) Sixty-five per cent of all cases of excess (*or deficient*) summer ice near Iceland (a result of increased atmospheric circulation) showed a plus ((*or minus*) temperature anomaly during the ensuing winter in Siberia.

(3) Seventy-five per cent of all cases of overnormal (*or subnormal*) pressure gradient between Denmark and Iceland coincided with a plus (*or minus*) winter temperature anomaly in Siberia. A 5 mm. increase of the gradient above normal for September–January corresponded with 1° C. plus anomaly; and a 3.6 mm. decrease below normal, with a 1° C. minus anomaly, for the Siberian winter.

(4) Eighty-five per cent of all cases of increase (*or decrease*) of the atmospheric circulation between the Azores and Iceland showed a plus (*or minus*) temperature anomaly.

(5) Seventy per cent of all cases of the Barents Sea summer ice limit, being farther south (*or north*) than usual, showed a minus (*or plus*) temperature anomaly. Decrease of 48′ in latitude corresponded to a lowering of the winter temperature in Siberia of about 0.5° C. and an increase of 1° C. to a raising of the temperature about 0.7° C.

(6) In 67 per cent of all cases an increase (*or decrease*) in the area of the ice-covered region corresponded with a minus (*or plus*) temperature anomaly, a warming of 0.5° taking place for each 280,000 km.^{2} of decrease in ice area and a cooling of 0.4° for each increase of 321,000 km.^{2}

(7) In 90 per cent of all cases a positive (*or negative*) temperature departure for November–February in the surface water of the Norwegian Sea corresponded to a positive (*or negative*) winter temperature anomaly in Siberia. An increase of surface water temperature of 0.5° corresponded to an increase of 1.5° in temperature in Siberia and a decrease of 0.5° to a decrease of 0.9°.

(8) In 76 per cent of all cases years of excess ice about Newfoundland coincided with warm winters in Siberia and years of deficient ice with cold winters.

The general conclusion is reached that anomalies in the hydrometeorological conditions of the Gulf Stream region show sufficient persistence to enable one to make practical use of them in forecasting the general nature of the winter in Siberia.—*B. M. V.*

ICE IN THE ARCTIC SEAS IN 1924

[Reprinted from Nature, London, April 25, 1925]

The annual report of the Danish Meteorological Institute is fuller than usual, especially as regards the Kara and Barents Seas and the east coast of Greenland, but, owing to lack of information, is very meager concerning the Beaufort Sea and coasts of eastern Siberia. In European Arctic regions the year on the whole was marked by less ice than is the rule during the spring and summer. In August and September the Kara Sea was exceptionally free from ice. The White Sea was clear in June and in the autumn froze much later than usual. In the northeastern part of the Barents Sea there was more open water than usual; in August, the only month for which there are data, it came very near to Franz Josef Land. During April and May very heavy pack extended to the southwest of Spitzbergen so far south as Bear Island, but the northern part of the west coast, as usual, was clear. In June conditions changed completely, resulting in a summer with exceptionally little ice in Spitzbergen waters. A Norwegian sloop circumnavigated North-East Land during August. On the east coast of Greenland the few observations suggest a narrower belt of close pack ice than usual. Iceland was touched by pack ice only during February. The Newfoundland Banks had little ice and few icebergs, and Davis Strait was fairly clear. The report is illustrated with several maps.

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING APRIL, 1925

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements the reader is referred to the REVIEW for January, 1924, **52**: 42 and January, 1925, **53**: 29.

From Table 1 it is seen that solar radiation intensities averaged slightly below normal values for April at all three stations. A noon reading of 1.50 gram-calories per min. per cm.² at Washington on the 7th almost equals the previous April maximum at that station of 1.51. For further particulars relative to the radiation intensities on this day see the paper by Mr. I. F. Hand in this REVIEW, p. 147, entitled, "The effect of local smoke on visibility and solar radiation intensities."

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged slightly above normal at the three stations for which weekly normals have been determined.

At Washington skylight polarization measurements made on five days give a mean of 60 per cent, with a maximum of 66 per cent on the 7th. These are slightly above normal values for April at Washington. At Madison measurements made on seven days give a mean of 55 per cent, with a maximum of 60 per cent on the 4th. These are slightly below normal values for April at Madison.

TABLE 1.—*Solar radiation intensities during April, 1925*

Washington, D. C.

[Gram-calories per minute per square centimeter of normal surface]

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
April 3	5.16					1.32					4.37
4	5.56				1.10						4.57
6	2.62					1.42					2.87
7	4.75		0.97		1.12	1.54	1.23	1.04	0.95	0.89	2.26
8	5.16					1.13					4.37
9	3.63	0.64	0.75	0.89	1.06	1.28					3.81
11	7.04			0.67	0.87	1.15					6.27
13	3.15					1.46	0.98				3.30
15	12.24				0.91						10.97
17	5.79		0.51	0.65							5.16
21	2.49	0.87	0.96	1.08	1.17						3.15
24	13.61					1.05					15.65
27	11.81				0.95	1.32					10.97
Means		**(0.76)**	**0.80**	**0.82**	**1.03**	**1.30**	**(1.10)**	**(1.04)**	**(0.95)**	**(0.89)**	
Departures		**+0.06**	**+0.05**	**−0.05**	**−0.03**	**−0.05**	**+0.01**	**+0.14**	**+0.20**	**+0.29**	

Madison, Wis.

Date	8 a.m.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	Noon
April 1	2.74						1.14				2.87
2	3.15				1.08						3.30
4	3.00			1.10	1.29	1.54	1.25				3.63
6	4.17				1.20		1.18				2.74
10	5.16					1.29	1.03				6.76
16	3.81				1.18						3.63
23	11.81				0 85						14.10
25	8.81			0.94	1.12	1.33					11.38
28	4.17			0.98	1.16						5.16
Means				**1.01**	**1.13**	**1.39**	**1.15**				
Departures				**−0.08**	**−0.09**	**−0.02**	**−0.07**				

TABLE 1.—*Solar radiation intensities during April, 1925.*—Con.

Lincoln, Nebr.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
April 21	10.97			0.76	0.99						12.24
25	5.56			0.78	1.07	1.35					3.63
29	3.63	0.88	1.00	1.14	1.31	1.54					3.15
Means		**(0.88)**	**(1.00)**	**0.89**	**1.12**	**(1.44)**					
Departures		**+0.11**	**+0.15**	**−0.10**	**−0.09**	**−0.01**					

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation					Average daily departure from normal		
	Washington	Madison	Lincoln	Chicago	New York	Washington	Madison	Lincoln
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Ap. 2	440	472	379	359	435	+51	+95	−59
9	447	418	444	276	416	+42	+27	+9
16	439	284	419	182	379	+19	−125	−19
23	338	461	526	344	337	−98	+30	+72
Deficiency since first of year on Apr. 29						−1,001	−1,596	−1,281

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The following table shows the average sea-level pressure for the month at a number of land stations on the coast and islands of the North Atlantic. The readings are for 8 a. m. 75th meridian time, and the departures are only approximate, as the normals were taken from the Pilot Chart and are based on Greenwich mean noon observations, which correspond to those taken at 7 a. m. 75th meridian time.

Station	Average pressure	Departure
	Inches	Inches
St. Johns, Newfoundland	29.86	−0.01
Nantucket	30.01	+0.03
Hatteras	30.02	+0.01
Key West	29.99	−0.03
New Orleans	30.03	+0.03
Swan Island	29.87	−0.11
Turks Island	30.00	−0.02
Bermuda	30.08	+0.08
Horta, Azores	30.23	+0.12
Lerwick, Shetland Islands	29.73	−0.07
Valencia, Ireland	29.86	−0.03
London	29.86	−0.01

It will be seen from the above table that there were no unusually large departures, although the average pressure for the month was somewhat higher than usual at Horta and slightly lower at Lerwick, denoting that both the Azores HIGH and Icelandic LOW were fairly well developed.

At Horta the barometric readings ranged from 30.62 inches on the 12th to 29.50 inches on the 30th, and at Lerwick from 30.16 inches on the 20th to 28.91 inches on the 15th.

The number of days with winds of gale force was considerably greater than usual over the western section of the steamer lanes. According to reports received up to date, the maximum number occurred in the 5-degree square between the 40th and 45th parallels and the 55th and 60th meridians, where gales were reported on 9 days. Conditions were apparently not far from normal over the territory north of the 45th parallel, east of the 35th meridian, with winds of gale force occurring on from 1 to 3 days.

The number of days with fog did not, on the whole, differ materially from the normal as shown on the Pilot Chart, the maximum amount occurring, as usual, on the Grand Banks, where fog was reported on 13 days.

The month began with moderate depressions over Nova Scotia and also off the northern coast of Europe. These LOWS both moved northeastward and were accompanied by no unusually heavy weather, except that on the 3d moderate northerly gales were encountered in the vicinity of Hatteras.

On the 4th there were two disturbances over the ocean; the first central near 40° N., 60° W., and the second, of much greater intensity, near 50° N., 20° W. By the 5th the western LOW was in the vicinity of Nova Scotia and western Newfoundland, and was surrounded by moderate winds. On the same date the eastern LOW was central about 5 degrees west of the southwest coast of Ireland,

and moderate to strong gales prevailed over the area between the 43d and 50th parallels and the 10th and 25th meridians.

Charts VIII to XIII cover the period from the 6th to 11th, inclusive, and an examination of these, together with the table of ocean gales and storms, will give an idea of conditions during this period.

On the 12th southerly gales prevailed over the region between the 35th and 45th parallels and the 50th and 60th meridians, and a few gale reports were received from vessels near the Azores and also off the coast of southern Europe.

On the 14th there were two well-developed disturbances over the ocean; the first central near 41° N., 50° W., and the second in the vicinity of Iceland, although the position of this second LOW was indeterminable due to lack of observations. They both moved slowly eastward, accompanied by moderate to strong gales, and on the 16th the center of the first was near 50° N., 32° W., and the second over the North Sea.

From the 17th to 19th moderate conditions were the rule over the ocean as a whole, although a few vessels in widely scattered localities reported moderate gales.

On the 20th there was a slight depression near Hatteras that afterwards developed into a severe disturbance. On the same date there was a second LOW of limited extent central near 53° N., 30° W., accompanied by southerly gales in the easterly quadrants; this moved rapidly northeastward, decreasing in force.

On the 21st and 22d the western LOW was central near 40° N., 55° W., and the storm area on both of these dates covered the greater part of the region between the 30th and 45th parallels, west of the 40th meridian.

On the 22d and 23d moderate gales were also encountered over the eastern section of the steamer lanes, as shown by report in table from Danish S. S. *United States*.

On the 23d St. Johns, Newfoundland, was near the center of the western disturbance, which remained nearly stationary during the next 24 hours, and then moved slowly east-southeastward, with a varying rate of translation, reaching the Azores by the end of the month. The storm area contracted and expanded from day to day, extending at times as far south as the 35th parallel, while the storm also varied considerably in intensity.

Ocean gales and storms, April, 1925

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
North Atlantic Ocean			° ′	° ′				Inches					
Canadian Leader, Br. S. S.	St. John, N. B.	Glasgow	50 00 N.	32 00 W.	4th	10a., 4th	5th	29.86	NW	NW., 8	NNW	–, 8	NW.–NNW.
Santa Marta, Am. S. S.	New York	Colon and return.	28 50 N.	74 15 W.	6th	11p., 6th	7th	29.74	E	E., 7	NE	NE., 8	SE.–E.
Deuel, Am. S. S.	Norfolk	Bremen	47 48 N.	14 32 W.	4th	8a., 6th	6th	29.44	NNW	N., 7	N	–, 8	NNW.,–N.
Cadilac, Br. S. S.	New York	Avonmouth	43 29 N.	41 13 W.	7th	5a., 7th	9th	29.65	NW	NNW., 4	W	NW., 10	NNW.–N.
Eastern Victor, Am. S. S.	do	Rotterdam	45 36 N.	31 45 W.	7th	4p., 7th	9th	29.40	S	WSW	NW	WNW., 9	S.–WSW.–W.
Nevada, Dan. S. S.	Newcastle	Philadelphia	55 57 N.	29 47 W.	8th	11a., 8th	9th	28.61	N	NW., 10	SW	NW., 10	Steady.
Andania, Br. S. S.	Cherbourg	New York	42 58 N.	45 10 W.	9th	2p., 9th	10th	29.20	SE	WSW	NNW	–, 9	SW.–W.–NW.
Abercos, Am. S. S.	New Orleans	Liverpool	45 50 N.	32 00 W.	9th	11a., 10th	10th	29.38	S	SSW., 8	WNW	–, 8	SSW.–WNW.
Mount Clay, Am. S. S.	New York	Hamburg	40 10 N.	64 10 W.	10th	4a., 11th	12th	29.91	SW	SW	S	SSW., 8	Steady.
Roepat, Du. S. S.	Marseille	Ouessant	46 45 N.	6 48 W.	12th	2p., 12th	12th	29.96	NW	S., 7	N	WNW., 8	Steady.
Am. Banker, Am. S. S.	New York	London	40 09 N.	48 23 W.	12th	8a., 13th	13th	29.98	S	SSW., 7	SSW	SSW., 8	Steady.
Caronia, Br. S. S.	Queenstown	New York	42 12 N.	57 24 W.	14th	7a., 14th	19th	29.86	N	N., 7	NE	–, 9	N.–NW.–NE.
Oscar II, Dan. S. S.	Oslo	do	57 05 N.	20 40 W.	14th	4p., 14th	15th	28.79	SW	SW., 7	NW	NW., 10	SW.–NW.
Boston City, Br. S. S.	Bristol	Philadelphia	45 30 N.	38 00 W.	16th	8a., 16th	16th	29.61	NW	NW., 5	NNW	NW., 9	Steady.
City of Cambridge, Br. S. S.	Swansea	New York	40 35 N.	65 30 W.	20th	4p., 20th	21st	29.69	N	N., 7	N	N., 10	NW.–N.
Kenbane Head, Br. S. S.	Greenock	Canada	53 05 N.	29 30 W.	20th	8p., 20th	21st	29.55	WSW	W., 8	W	W., 8	Steady.
Boston City, Br. S. S.	Bristol	Philadelphia	41 30 N.	60 00 W.	21st	2a., 21st	22d	29.66	NNE	NNE., 9	N	NNE., 12	Steady.
Andalusier, Belg. S. S.	New York	Havre	42 32 N.	53 20 W.	20th	2a., 21st	25th	29.55	E	ENE., 8	S	SSW., 10	E.–ENE.
United States, Dan. S. S.	do	Christianssand	50 06 N.	38 20 W.	21st	4p., 21st	24th	29.91	N	N., 6	NW	–, 8	Steady.
Lapland, Br. S. S.	Gibraltar	New York	39 18 N.	62 35 W.	21st	2p., 21st	22d	29.45	NE	N., 10	NE	NE., 12	Steady
Saucon, Am. S. S.	Italy	do	38 41 N.	55 31 W.	22d	1a., 23d	24th	29.54		SW., 9	NW	SW., 9	
Anaconda, Am. S. S.	English Channel.	do	43 35 N.	44 02 W.	23d	10a., 24th	24th	29.85	SSW	SW., 7	SW	–, 9	SSE.–SW.
Howick Hall, Br. S. S.	London	Baltimore	39 40 N.	44 50 W.	24th	8a., 26th	27th	29.35	S	Var. 9	NNW	–, 9	SSE.–SW.–NNW.
Montpelier, Am. S. S.	Colon	London	42 00 N.	35 00 W.	24th	6a., 27th	28th	29.14	SSW	SSE., 5	SSE	SSE., 10	S.–SSE.
Saguache, Am. S. S.	Rotterdam	Galveston	40 00 N.	32 30 W.	28th	11p., 28th	30th	29.50	W	W., 7	W	W., 8	W.–SW.–W.
Indian Ocean													
Port Campbell, Br. S. S.	London	Melbourne	43 17 S.	71 21 E.	1st	Mid., 1st	3d	28.43	W. by N.	W	W. by S.	–, 8	
Mahana, Br. S. S.	do	do	43 00 S.	48 40 E.	6th	10a., 6th	7th	29.48	SW	W., 4	WSW	WSW., 8	NW.–WNW.–W–WSW.
Mediterranean Sea													
Egremont, Am. S. S.	Bombay	New York	31 38 N.	32 00 E.	2d	4p., 2d	4th	29.47	E	E., 6	NW	NW., 9	E.–N.–NW.
Red Sea													
Bengal Maru, Jap. S. S.	Calcutta	Suez	14 38 N.	41 55 E.	12th	4a., 13th	13th	29.71	ENE	S., 7	SSE	–, 8	ENE.–S.
North Pacific Ocean													
Victorious, Am. S. S.	Honolulu	Yokohama	*31 00 N.	*145 00 E.	2d	3a., 3d	3d	29.73	E	NE., 7	NE	ENE., 8	NE.–E.–NE.
Tenyo Maru, Jap. S. S.	Yokohama	San Francisco	34 33 N.	156 53 E.	3d	6a., 5th	5th	29.75	SE	SE., 7	S	S., 8	
Pres. McKinley, Am. S. S.	Victoria	Yokohama	47 00 N.	164 45 E.	4th	12p., 5th	7th	29.19	SW	SSW., 10	W	SSW., 10	SSE.–SSW.–W.
Talthybius, Br. S. S.	Puget Sound	do	47 35 N.	169 29 E.	4th	Noon, 6th	8th	29.33	WNW	SSW., 10	WNW	SSW., 10	SSW.–WSW.
Pres. Cleveland, Am. S. S.	San Francisco	Yokohama	33 N.	145 20E.	5th	9a	5th	29.18	SSW	SSW., 6	NNE	N., 10	SSW.–NNE.

* Approximate.

Ocean gales and storms, April, 1925—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
			° ′	° ′				Inches					
Irene, Am. sch	Honolulu	Grays Harbor	43 11 N.	144 W.	6th	2a	6th	29.66	SW	SE., 8	N	SE., 8	SW.-SE.
Arabia Maru, Jap. S. S.	Victoria	Yokohama	48 45 N.	167 10 E.	6th	Noon, 6th	7th	29.19	SSW	S. 8	WNW	WSW., 9	S.-W.
West Niger, Am. S. S.	Columbia River.	do	47 10 N.	170 30 E.	6th	3a., 10th	11th	29.38	WSW	SE., 8	WSW	SW., 9	SE.-SW.
Tokiwa Maru, Jap. S. S	Vancouver	do	52 N.	155 W.	7th	6p., 7th	9th	29.29	S	SW., 6	NW	WNW., 9	
Achilles, Br. S. S	Yokohama	Victoria	46 43 N.	168 53 E	8th	1a., 8th	9th	29.96	W	W., 9	WNW	W., 9	
Tamaha, Br. S. S	Hongkong	San Francisco	23 50 N.	118 50 E.	8th	4a., 8th	9th	30.11	NE	NE., 8	N	NE., 8	Steady NE.
Makaweli, Am. S. S	Port Allen	do	32 40 N.	137 50 W.	9th	4a., 9th	10th	29.22	NW	NW., 8	NW	NW., 9	
Talthybius, Br. S. S	Puget Sound	Yokohama	42 24 N.	154 E.	9th	2p., 9th	10th	29.42	SE	SSW., 8	NW.-N	{SE {NNW., 9	}S.-SW.
West Ivan, Am. S. S	Hongkong	San Francisco	41 50 N.	155 E.	9th	10p., 9th	11th	29.40	SSE	S., 8	WNW	S., 8	
Dickenson, Am. S. S	Midway Island.	Honolulu	26 07 N.	169 50 W.	9th	6p., 10th	12th	30.12	ENE	ENE., 8	ENE	ENE., 9	E.-ENE.
Aorangi, Br. S. S	Victoria	do	38 16 N.	141 27 W.	12th	1a., 12th	13th	29.44	N	NW., 8	N	NW., 8	N.-W.-NW.
West Keats, Am. S. S.	Dairen, Japan	San Francisco	39 40 N.	148 50 E.	13th	4p	13th	29.53	ESE	ESE., 9	SW	ESE., 9	ESE.-SW.
Yokohama Maru, Jap. S. S.	Victoria	Yokohama	52 36 N.	148 13 W.	14th	7a., 14th	15th	29.78	W	NW., 8	WNW	NW., 8	
Mauna Ala, Am. S. S.	Bellingham	Hawaii	42 48 N.	135 03 W.	15th	9a., 15th	17th	29.52	SSW	W., 5	W	WSW., 8	SSW.-W.-WSW
Meiyo Maru, Jap. S. S.	Mororan, Japan.	Tacoma	46 19 N.	153 30 W.	26th	2a., 29th	29th	29.63	NW	W.-S., 7	W. S	WNW., 8	
West Jessup, Am. S. S.	Yokohama	Portland	49 30 N.	150 W.	26th	8p., 27th	28th	29.41	WNW	SW., 8	SW	{W., 8 {SW., 8	
Africa Maru, Jap. S. S.	do	Victoria	48 07 N.	174 49 E.	29th	Noon	29th	29.72	WSW	WSW	W	WSW., 8	WSW.-W.

NORTH PACIFIC OCEAN

By WILLIS EDWIN HURD

April, like the preceding month, witnessed the almost complete control of the North Pacific anticyclone over the eastern waters of the ocean. It fluctuated somewhat, cresting near the 35th parallel, between the 165th and 180th meridians, during the first half of the month, then variously from the 35th to 45th parallels, 145th meridian, during the remainder. It was but little encroached upon by cyclonic influences from the north, and was entered by only one depression from elsewhere—a disturbance of generally slight intensity which originated apparently near 30° N., 140° W., on the 7th. This LOW caused unsettled weather and some moderate gales over the central part of the California-Hawaiian routes until the 15th, when it moved northward and joined with the lower projection of the cyclone which, then central over the northern part of the Gulf of Alaska, extended down the coast as far as the 40th parallel.

A small cyclone also hung over and east of Midway Island from the 23d to the 28th, though slowly drifting northward. No gales have been reported as accompanying its movements.

Consequent upon the general position and intensity of the HIGH, the northeast trades were unusually steady over a great part of their average area, and the easterly winds on the southern slope of the anticyclone, unusually strong. At Honolulu the average wind velocity was again, as in March, the highest of record for the month being for April 11.8 m. p. h. the wind blowing with exceptional constancy from the east. The maximum velocity was at the rate of 34 miles an hour from the east on the 17th, but velocities equaling or exceeding 25 miles an hour occurred on 10 days.

Throughout the Aleutian region, including the Gulf of Alaska, cyclonic conditions were maintained during about three-fourths of the month, with the average center of the depression lying over the northwestern part of the gulf. On several days the LOW moved northward over Alaska or the Arctic Ocean, and thus only slightly affected the weather along the northern sailing routes. The average pressure over the whole area from Dutch Harbor and St. Paul to Juneau was below normal, although no readings lower than 29 inches were recorded on land or sea.

From the Gulf of Alaska, or thereabouts, LOWS connected with the oscillating Aleutian cyclone entered the mainland on the 3d, 6th, 9th, 16th, 18th, 21st, and 28th.

The following table of pressure data is made from the records at various island stations, as well as from a few American coast stations. Averages are for both 8 a. m. and 8 p. m. observations, 75th meridian time, except as noted:

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
Dutch Harbor *	† 29.76	−0.06	30.30	14th	29.24	19th.
St. Paul	† 29.72	−0.08	30.32	13th	29.08	19th.
Kodiak	† 29.65	−0.15	30.24	10th	29.12	29th.
Midway Island *	† 30.02	−0.08	30.38	5th	29.52	24th.
Honolulu	30.08	+0.01	30.20	17th	29.97	8th.
Juneau	29.87	−0.09	30.47	26th	29.35	30th.
Tatoosh Island	30.02	−0.02	30.46	25th	29.58	18th.
San Francisco	30.02	−0.02	30.30	17th	29.68	21st.
San Diego	30.00	+0.04	30.18	1st	29.70	21st.

* For 28 days only.
† P. m. observations only.

During the first four days of April the Asiatic HIGH was nonexistent on the China coast, but from then until the 20th it was well built up, so that a fairly strong northeast monsoon current was reported on a few days from the Formosa Channel and parts of the China Sea. After the 20th unsettled spring conditions of pressure were maintained over the southern waters of the Far East until the end of the month.

Several cyclones entered the Pacific from Japan, and rough weather—rougher than in any other part of the Pacific—prevailed in that neighborhood on a number of days during the early half of the month. From the 4th to the 10th high winds were of almost daily occurrence along that portion of the northern steamer lanes between 160° E. and the 180th meridian. Winds as high as force 10 occurred on two or three days, while no forces exceeding 9 were recorded elsewhere on any day. Few winds exceeding force 7 were observed from the 18th to 25th, inclusive. In west longitudes gales were scattered and, as elsewhere, occurred mostly during the early half of the month.

Snow squalls to heavy snows occurred in middle and higher latitudes on several days. The American steamship *West Jessup* encountered heavy snow in 49° 30′ N., 150° W., with air temperature of 36°, as late as April 27.

No evidences of a tropical storm for this month have been deduced from any of the reports yet received. Off the Mexican and Central American west coast the usual light variable winds of the season were prevalent, with a tendency toward becoming gentle northwesterly in the upper reaches.

Fog, from isolated patches to wide, dense banks, was observed on the horizon or passed through by vessels in many parts of the ocean, generally north of the 30th parallel. The phenomenon was most frequent in east longitudes, where it occurred largely after the middle of April, except near 30° N., 155° E., where it was observed on the 4th to 6th. Along the American coast between the 40th and 20th parallels fog prevalence showed a decided increase over that of March. Off Cape San Lucas it was reported on five days.

NOTES

Panaman motor ship *City of San Francisco*, San Pedro to Panama, Capt. C. Zastrow; observer, David Porter, second officer:

April 11 to 14, very hazy. This haze is very likely smoke, but in the early morning before sunrise it is impossible to distinguish this from the true "Cirrus haze." Our courses lie close to the land, which makes it more difficult. Approaching San Jose de Guatemala, this haze or smoke was so thick as to render the lights of the town, ordinarily visible 10–12 miles, invisible until within a mile.

British S. S. *London Shipper*, San Francisco to Balboa, Capt. D. Buckley; observer, J. Kenner, second officer:

April 29, 2:30 a. m., local time. Extraordinary visibility. Bona Island Light, 8° 34′ N., 79° 35′ W., being plainly visible from southward 36 miles distant.

American tanker *India Arrow*, Shanghai to San Francisco, Capt. S. C. Ibsen; observer, Jos. B. Smyth, second officer:

April 19, 2:05 p. m., local time, in 36° 23′ N., 146° E., the temperature of the sea water dropped suddenly from 66° to 40°, that of the air falling rapidly from 64° to 56°, and the water changing from blue-green to dark olive-green. Wind northeasterly; force, 1; barometer, 30.43 (corrected). Weather fine, clear sky, horizon hazy, sea smooth. Temperature of the sea went up slowly until it reached 60° at midnight, when we reached 37° 04′ N., 148° 08′ E.

GALES IN THE INDIAN OCEAN AND OFF THE AFRICAN COAST

By Albert J. McCurdy, Jr.

Indian Ocean.—Weather reports thus far received from vessels that traversed the shipping routes of the Indian Ocean in April, 1925, indicate only two disturbances of any consequence.

The first, a northwesterly gale, accompanied by frequent rain and hail squalls, together with high seas, was experienced on the 1st, 2d, and 3d by the British S. S. *Port Campbell*, Capt. P. J. Reynolds, London to Melbourne. Mr. J. Buchan, observer, reports that the lowest barometer recorded was 28.43 inches (uncorrected) at midnight on the 1st in 43° 17′ S., 71° 21′ E. The wind at the time was W., force 8.

A report of the second gale was received from the British S. S. *Mahana*, London to Melbourne. The observers, Messrs. F. Smith, H. Smith, and J. Rogers, state that a moderate gale began on the 6th, accompanied by high seas and rain showers. The lowest pressure observed was 29.48 inches, occurring at 10 a. m. on the 6th in 43° S., 48° 40′ E. The wind at this time was W., force 4. This gale lasted throughout the evening of the 7th, and during that time the wind increased to force 8, with shifts to the NW., WNW., W., and WSW.

Mediterranean Sea.—Of the cyclonic disturbances occurring in the Mediterranean Sea during April, only one of any importance has been reported. This was a depression north of Port Said that appeared on the 2d and caused until the 4th strong breezes to strong gales, with accompanying rain squalls and rough seas. The American S. S. *Egremont*, Capt. D. Holth, Bombay to New York, came within its influence on the 2d. Mr. C. E. Dunton, observer, reports that the lowest pressure was 29.47 inches, occurring at 4 p. m. on the 2d in 31° 38′ N., 32° E. The wind at this time was E., force 6, but later shifted to N. and NW. and increased to force 9.

Red Sea.—The only reported gale of any consequence was a disturbance encountered on the 12th and 13th in the vicinity of the Kamaran Islands by the Japanese S. S. *Bengal Maru*, Capt. M. Araki, Calcutta to Suez. Mr. R. Neyazaki, observer, states that the lowest barometric reading, 29.71 inches, was recorded at 4 a. m. on the 13th in 14° 38′ N., 41° 55′ E. The wind at this time was S., force 7, and increased to a fresh gale that lasted until 3 p. m. of the 13th.

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

Like the two immediately preceding months, April, 1925, was warm in practically all parts of the country, especially east of the Mississippi and south of the Ohio during the last 10 days of the month. Thus the temperature has been above normal for three consecutive months.

Precipitation, as a rule, was mostly below normal, except in Arkansas, Oklahoma, western and northern Texas, where drought was relieved during the last decade.

As in the two immediately preceding months, pressure in Alaska and the Canadian Northwest was lower than usual; pressure in the North Pacific HIGH was, however, above normal. No cases of general and pronounced southward flows of polar air occurred.

CYCLONES AND ANTICYCLONES

By W. P. DAY

The number of low-pressure areas charted during April showed a decided decrease as compared with the colder months preceding, indicative of the lessened interchange of air between the pole and the Equator with the arrival of warmer weather. Also most of the cold high-pressure areas coming from Canada pushed southward from the region of Hudson Bay, while only one came southward from the Mackenzie Valley. In general this may be attributed to the effect of Hudson Bay in retarding the rise in temperature over northeastern Canada, giving a strong temperature gradient from east to west over northern Canada and a preponderance of high pressure over the colder regions. These Hudson Bay HIGHS affected only the Northeastern States, while the single HIGH from northwestern Canada on the 27th and 28th brought cool weather generally east of the Rockies.

FREE-AIR SUMMARY

By V. E. JAKL

Free-air temperatures showed positive departures of practically the same amount as the temperatures at the surface (Chart III in this REVIEW). Thus, in eastern North Dakota both the surface departure and the departure up to the limits of observation were about 9° F. (Ellendale, Table 1). The slight diminution of the departure with altitude noted at Ellendale and some other stations, and the slight increase at still others, is very likely due to the fewer observations at the higher levels; therefore, a practically uniform departure at all observed altitudes for all stations may be taken for granted. Some indication of the cause of these conditions is shown by the observations at Broken Arrow, Drexel, and Ellendale on the 21st and 22d, made in south component winds of considerable depth in the front of an extensive and well-defined depression. On one or both of these dates temperatures from 9° to 15° F. above normal up to about 4,000 meters were recorded.

Notwithstanding the higher average free-air temperatures, there was about the usual amount of cloudy weather and precipitation; consequently the relative humidity was about normal and the vapor pressure above normal over all stations and at all altitudes for which reliable averages were obtained.

Table 2, together with the resultants of pilot balloon observations, shows that above 2,000 meters the wind direction was generally about normal, i. e., nearly due west, and of slightly less than normal velocity. Below 2,000 meters, the winds were of variable strength and velocity, both from level to level and from station to station. At these lower levels, therefore, as might be expected, the wind resultants showed no close agreement with the normal.

In considering the average free-air winds for the month a certain relation between them and the character of precipitation is at once apparent. As the precipitation approaches the summer type of occasional showers and thunderstorms the wind directions and velocities are found to become correspondingly more variable than during the colder season. There is a tendency to an instability of the air peculiar to the spring months, due to lag in the seasonal increase of temperature aloft. This instability, combined with the rapid changes in wind direction, apparently accounts for many if not most of the cases of precipitation occurring during this time of year.

On numerous occasions during this month showers and thunderstorms began simultaneously with change in direction of wind and fall in temperature—or with fall in temperature alone—observed at the surface. To what depth these changes extend aloft can not often be determined, owing to the danger of flying kites during showers and thunderstorms. However, there are some observations available made near enough to the time of occurrence of precipitation to serve as illustrations. At Drexel on the 13th a record finished just before a thundershower began clearly shows a rapid fall in temperature and rise in humidity aloft and rising temperature and falling humidity near the ground, this change to opposite values causing a rapid approach to a dry adiabatic lapse rate and eventually falling temperature on the ground. The ensuing thunderstorm with its attendant drop in surface temperature was evidently caused by a wedge of cold air that had built up from the ground immediately to the northwest of Drexel. The free-air record for Drexel on this date is shown in the following table:

Altitude, M. S. L. meters	Time	Temperature	Relative humidity	Wind direction	Time	Temperature	Relative humidity	Wind direction
		° C.	Per cent			° C.	Per cent	
396	7:16 a. m.	13.5	72	WNW	1:10 p. m.	23.0	30	SW.
Surface:								
1,000	7:31 a. m.	12.7	48	NW	1:01 p. m.	15.7	41	W.
2,000	7:47 a. m.	7.5	33	NNW	12:44 p. m.	4.9	67	WNW.
3,000	8:22 a. m.	1.1	34	NW	12:27 p. m.	−3.8	42	NW.
4,000	8:48 a. m.	−4.3	25	WNW	12:11 p. m.	−10.4	45	W.
5,000	9:42 a. m.	−9.4	14	WNW	11:44 a. m.	−14.6	34	W.
6,000	11:05 a. m.	−15.9	25	W				

The effect of the eastward movement of this condition is shown by the surface record at Royal Center, 500 miles east of Drexel, where four hours later a thundershower occurred, with an abrupt wind shift from south to west and decided fall in surface temperature. The morning observation at Royal Center shows southeast winds at the surface veering to southwest aloft, while that of the following morning shows northerly winds at the surface backing to westerly aloft. The pressure distribution shows Drexel in the rear of a LOW on the morning of the 13th, and Royal Center to the south of

the LOW on the evening of the same day, the LOW having in the meantime passed northeastward.

A somewhat similar succession of events at two stations is noted on the 26th over Broken Arrow and Groesbeck, about 300 miles apart in a north-south line. A thunderstorm, attended by a shift in wind from south to northwest and a drop in temperature at the surface, began at Broken Arrow at 6 p. m., and 4 hours later at Groesbeck, where the drop in temperature was accompanied by a shift from southwest to northwest. Kite and pilot balloon observations at these stations show a change from southerly winds veering with altitude on the 26th to northwesterly winds backing with altitude on the 27th, attending the development of a LOW in the southwest and its movement eastward.

A few instances of easterly winds aloft are noted, principally during the first few days of the month in the southern portion of an area of high pressure that moved southeastward from the Canadian Northwest to the Southeastern States. It is significant, however, that in only a few instances were these easterly winds observed to very high altitudes, as in spring the normal latitudinal temperature gradient is still strongly established, while easterly winds extending to high altitudes require a reversal of this temperature gradient to a considerable depth.

The principal instances of strong winds aloft are noted on the 23d and 24th in connection with a pronounced LOW that moved northward over middle sections of the country. Stations in the immediate influence of this LOW showed strong winds on the ground, increasing rapidly with altitude, while at stations more remote from the LOW the wind increased from light on the ground to gale force aloft.

The highest kite flight of the month reached 7,023 meters at Ellendale, on the 10th. This lacked only a few meters of equaling the previous record established at that station for highest altitude above sea level reached in this country in recent years. The flight was made to the south of a LOW approaching from the northwest, and showed southwest winds at the surface veering to northwesterly in the upper altitudes, with an inversion in temperature to 1,000 meters and a continuous fall in temperature at the rate of nearly 0.8° per 100 meters to the topmost altitude of the observation.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1925*

TEMPERATURE (° C.)

Altitude M. S. L. (m.)	Broken Arrow, Okla. (233 m.) Mean	Departure from 7-yr. mean	Drexel, Nebr. (396 m.) Mean	Departure from 10-yr. mean	Due West, S. C. (217 m.) Mean	Departure from 5-yr. mean	Ellendale, N. Dak. (444 m.) Mean	Departure from 8-yr. mean	Groesbeck, Tex. (141 m.) Mean	Departure from 7-yr. mean	Royal Center, Ind. (225 m.) Mean	Departure from 7-yr. mean
Surface	19.0	+3.2	14.1	+4.9	18.6	+1.2	9.9	+4.1	20.1	+1.6	13.5	+2.2
250	18.9	+3.2			18.3	+1.2			19.3	+1.5	13.3	+2.2
500	18.7	+4.5	13.6	+5.1	16.0	+1.2	9.5	+4.0	17.6	+1.4	11.7	+2.9
750	17.1	+4.4	12.7	+5.8	14.3	+1.2	8.4	+4.3	16.4	+1.3	10.9	+3.4
1,000	15.8	+4.2	11.2	+5.4	13.2	+1.4	7.5	+4.5	15.5	+1.2	9.9	+3.7
1,250	14.6	+4.2	9.7	+4.9	11.8	+1.3	6.1	+4.2	15.1	+1.6	9.1	+4.1
1,500	13.2	+3.9	8.3	+4.5	10.1	+1.0	4.6	+3.9	14.3	+1.5	8.0	+4.1
2,000	10.5	+3.7	5.2	+3.7	6.6	+0.5	1.3	+3.1	12.3	+1.6	5.4	+3.9
2,500	7.5	+3.6	2.0	+3.1	4.0	+0.4	−2.6	+2.0	9.9	+1.9	3.0	+4.1
3,000	4.4	+3.6	−1.3	+2.6	1.0	−0.1	−6.2	+1.4	7.0	+1.8	0.9	+4.7
3,500	1.3	+3.6	−4.2	+2.7	−2.6	−1.1	−9.8	+0.8	4.3	+1.9	−1.8	+4.6
4,000	−1.6	+3.7	−7.3	+2.7	−6.6	−2.8	−13.2	+0.6	1.8	+2.5	−4.5	+4.1
4,500	−4.5	+3.7	−10.7	+2.3			−17.2	−0.4			−7.2	+4.2
5,000	−7.8	+3.6	−13.4	+2.5			−21.2	−1.1				

RELATIVE HUMIDITY (%)

Altitude M. S. L. (m.)	Broken Arrow Mean	Departure	Drexel Mean	Departure	Due West Mean	Departure	Ellendale Mean	Departure	Groesbeck Mean	Departure	Royal Center Mean	Departure
Surface	64	0	60	−5	55	−5	62	−5	70	−1	61	−2
250	64	0			55	−5			71	0	61	−2
500	63	0	57	−7	57	−4	62	−4	71	+2	60	−3
750	62	0	52	−11	57	−5	60	−4	68	+2	57	−5
1,000	61	+1	52	−10	55	−7	60	−2	64	+3	54	−7
1,250	59	+1	52	−9	58	−4	61	0	56	0	50	−9
1,500	60	+4	51	−8	64	+2	59	0	50	−1	49	−9
2,000	58	+6	51	−6	70	+9	54	−2	40	−5	50	−7
2,500	56	+5	53	−4	64	+9	55	0	37	−6	46	−9
3,000	53	+3	53	−3	60	+11	54	−1	41	−1	45	−8
3,500	49	−3	53	−3	59	+14	56	0	48	+4	41	−12
4,000	46	−3	48	−7	62	+17	60	+4	47	0	31	−19
4,500	50	+1	42	−12			65	+9			21	−27
5,000	58	+5	39	−13			70	+15				

VAPOR PRESSURE (mb.)

Altitude M. S. L. (m.)	Broken Arrow Mean	Departure	Drexel Mean	Departure	Due West Mean	Departure	Ellendale Mean	Departure	Groesbeck Mean	Departure	Royal Center Mean	Departure
Surface	14.12	+2.20	9.44	+1.81	12.08	−0.25	7.36	+1.25	16.53	+1.05	9.72	+0.83
250	14.01	+2.20			11.92	−0.20			16.08	+1.31	9.60	+0.86
500	12.47	+2.01	8.88	+1.62	10.82	+0.03	7.19	+1.25	14.55	+1.51	8.54	+1.01
750	11.17	+1.83	7.75	+1.27	9.77	−0.02	6.64	+1.38	12.75	+1.12	7.67	+0.91
1,000	10.17	+1.78	7.07	+1.15	8.78	−0.18	6.35	+1.58	11.08	+0.92	6.91	+0.81
1,250	9.12	+1.61	6.34	+0.97	8.25	+0.11	6.01	+1.68	9.24	+0.47	6.09	+0.60
1,500	8.43	+1.68	5.62	+0.77	8.06	+0.72	5.31	+1.43	7.63	+0.26	5.52	+0.51
2,000	6.46	+1.19	4.54	+0.59	6.89	+1.15	3.80	+0.76	5.30	−0.29	4.66	+0.49
2,500	4.94	+0.74	3.72	+0.50	5.34	+1.14	2.98	+0.55	4.21	−0.31	3.41	+0.11
3,000	3.70	+0.31	2.95	+0.28	4.38	+1.25	2.07	+0.14	4.10	+0.41	2.84	+0.22
3,500	2.72	−0.09	2.35	+0.18	3.66	+1.24	1.61	+0.04	4.00	+0.81	1.98	−0.26
4,000	2.18	+0.06	1.67	−0.02	3.33	+1.38	1.31	+0.06	3.71	+1.02	1.22	−0.69
4,500	1.95	+0.14	1.26	−0.06			1.11	+0.17			0.69	−0.85
5,000	1.72	+0.15	1.06	−0.01			0.93	+0.23				

TABLE 2.—*Free-air resultant winds (m. p. s.) during April, 1925*

Altitude, M. S. L. m.	Broken Arrow, Okla. (233 m.) Mean Dir.	Vel.	7-year mean Dir.	Vel.	Drexel, Nebr. (396 m.) Mean Dir.	Vel.	10-year mean Dir.	Vel.	Due West, S. C. (217 m.) Mean Dir.	Vel.	5-year mean Dir.	Vel.
Surface	S. 9°E.	3.5	S. 1°W.	2.8	S. 12°E.	1.8	S. 26°E.	0.4	S. 60°W.	1.3	S. 82°W.	1.4
250	S. 9°E.	3.6	S. 1°W.	2.9					S. 61°W.	1.3	S. 79°W.	1.5
500	S. 1°E.	4.9	S. 9°W.	4.2	S. 14°E.	2.5	S. 10°E.	0.6	S. 67°W.	1.7	S. 75°W.	2.4
750	S. 3°W.	5.3	S. 13°W.	5.2	S. 14°E.	2.9	S. 38°W.	0.6	S. 60°W.	1.5	S. 69°W.	3.0
1,000	S. 16°W.	5.3	S. 25°W.	5.6	S. 6°E.	2.6	S. 55°W.	1.2	S. 60°W.	1.5	S. 63°W.	3.7
1,250	S. 33°W.	5.4	S. 36°W.	5.8	S.	1.8	S. 70°W.	2.0	S. 52°W.	2.0	S. 66°W.	5.1
1,500	S. 43°W.	5.1	S. 50°W.	6.4	S. 20°W.	1.7	S. 78°W.	3.0	S. 63°W.	2.9	S. 69°W.	6.3
2,000	S. 57°W.	6.3	S. 60°W.	7.6	S. 28°W.	2.1	S. 86°W.	4.3	W.	3.1	S. 81°W.	7.7
2,500	S. 55°W.	7.1	S. 69°W.	8.4	S. 73°W.	3.8	S. 88°W.	6.2	S. 83°W.	6.2	S. 82°W.	9.8
3,000	S. 70°W.	6.4	S. 79°W.	8.3	S. 79°W.	6.3	S. 88°W.	8.7	S. 70°W.	6.2	S. 83°W.	10.1
3,500	S. 76°W.	8.6	S. 83°W.	11.0	S. 85°W.	6.8	S. 88°W.	10.1	N. 75°W.	7.8	N. 84°W.	11.8
4,000	S. 84°W.	11.6	S. 83°W.	12.4	N. 64°W.	4.7	N. 86°W.	11.1	S. 71°W.	6.3	N. 77°W.	13.6
4,500	N. 87°W.	12.4	S. 82°W.	14.2	N. 73°W.	7.8	N. 78°W.	12.9	N. 67°W.	13.0	N. 52°W.	14.9
5,000	N. 66°W.	13.7	N. 85°W.	13.7	N. 73°W.	5.9	N. 82°W.	14.9				

Altitude, M. S. L. m.	Ellendale, N. Dak. (444 m.) Mean Dir.	Vel.	8-year mean Dir.	Vel.	Groesbeck, Tex. (141 m.) Mean Dir.	Vel.	7-year mean Dir.	Vel.	Royal Center, Ind. (225 m.) Mean Dir.	Vel.	7-year mean Dir.	Vel.
Surface	N. 14°W.	1.4	N. 11°W.	1.6	S. 2°E.	3.0	S. 5°E.	2.5	S. 82°E.	0.7	S. 52°W.	1.9
250					S. 1°E.	4.0	S. 3°E.	3.2	S. 70°E.	0.6	S. 45°W.	2.1
500	N. 7°W.	1.3	N. 11°W.	1.5	S. 2°W.	5.3	S. 4°W.	4.7	S. 18°W.	1.4	S. 42°W.	4.0
750	N. 3°W.	0.7	N. 20°W.	0.8	S. 5°W.	5.6	S. 10°W.	5.4	S. 75°W.	2.2	S. 50°W.	5.1
1,000	S. 60°W.	0.8	N. 53°W.	1.0	S. 9°W.	6.4	S. 21°W.	6.1	W.	2.4	S. 55°W.	5.8
1,250	S. 63°W.	1.7	N. 61°W.	1.8	S. 21°W.	6.8	S. 32°W.	6.5	N. 78°W.	3.7	S. 68°W.	6.5
1,500	S. 68°W.	2.3	N. 64°W.	2.3	S. 30°W.	7.0	S. 37°W.	7.2	N. 73°W.	5.2	S. 77°W.	7.3
2,000	S. 60°W.	3.9	N. 80°W.	3.0	S. 42°W.	6.8	S. 48°W.	8.0	N. 79°W.	6.3	S. 84°W.	8.3
2,500	S. 64°W.	4.9	N. 88°W.	4.6	S. 65°W.	4.9	S. 58°W.	8.5	N. 32°W.	6.4	W.	8.4
3,000	S. 81°W.	6.5	N. 82°W.	6.2	S. 77°W.	5.6	S. 64°W.	10.5	N. 4°W.	10.5	N. 86°W.	9.8
3,500	S. 85°W.	6.9	N. 85°W.	7.7	S. 74°W.	6.8	S. 69°W.	10.4	N. 2°W.	10.2	S. 83°W.	11.2
4,000	N. 59°W.	10.6	N. 79°W.	8.8	N. 58°W.	5.4	S. 85°W.	11.9	N. 68°W.	15.1	S. 87°W.	13.5
4,500	N. 46°W.	12.9	N. 64°W.	8.7					N. 67°W.	14.0	N. 89°W.	11.4
5,000	N. 68°W.	9.0	N. 74°W.	15.3								

THE WEATHER ELEMENTS

By P. C. Day, In Charge of Division

PRESSURE AND WINDS

The movement of cyclones and anticyclones assumed the lessened activity, as compared with the months immediately preceding, common to the midspring month. Sharp changes in atmospheric pressure were notably absent and the pressure gradients were usually slight, though at Havre, Mont., the sea-level pressure on the 23d, 29.20 inches, was the lowest of record in April for that station. As the pressure was low over the entire Northwest on that date, the gradients were moderate in all directions, and no widespread severe winds were experienced, though remarkably heavy snow fell over portions of southwestern Montana. In general the anticyclones were shallow, and though some of them maintained well-defined courses across the country, the rainfall resulting therefrom was usually confined to narrow limits and was rarely heavy.

The principal anticyclone appeared over the Hudson Bay region on the morning of the 20th and gradually overspread the northeastern States during the following two days, causing the most important fall in temperature over the Atlantic coast districts experienced during the month. Other anticyclones were mainly unimportant and were confined largely to the regions from the Great Lakes eastward, except that occurring early in the first decade, which moved into the United States from the Canadian Northwest and developed considerable importance as a weather-controlling factor from the Great Lakes eastward about the 4th to 6th, though temperature falls were less pronounced than would ordinarily be expected.

The average atmospheric pressure was slightly higher than normal from the Missouri Valley eastward to the Atlantic coast, including the Canadian Maritime Provinces, and also over small areas near the West Gulf coast and locally in the vicinity of southern California. Elsewhere the average pressure was moderately below normal.

Compared with the preceding month, the pressure was lower by considerable amounts over all parts of the United States and Canada save for a small area in the Lake Superior region.

The highest average pressure covered the upper Lake region, a condition usually existing in April. The pressure gradients were mainly small and therefore exerted no marked effect upon the wind circulation. As a consequence the prevailing winds varied materially at near-by points, but on the whole they were from southerly points over the interior and southern districts.

Local storms were reported at some point in the country on nearly every day, but they were not severe over wide areas, though they were rather numerous on the 18th to 20th from Kansas and Nebraska eastward to the central Appalachian Mountain region.

TEMPERATURE

The monthly means were for the third consecutive month above the normal in practically all parts of both the United States and Canada, and for the fourth consecutive month over the interior and Northwest; they were the highest ever observed in April at many points in the South from Texas eastward; and the maximum temperatures were the highest ever observed in April over much of the country from the Mississippi River eastward and in portions of the Southern Plains.

The first few days of the month were moderately cool over the Southeast and freezing temperatures occurred locally in the northern portions of the East Gulf States and the western parts of the Carolinas. At the same time the lowest temperatures of the month were reported in portions of the far Southwest, where, at exposed points in the mountains, readings below zero were observed.

Following this cool spell the day-to-day changes were small and temperatures were mainly above normal until the 20th and 21st, when sharp falls occurred from the Ohio Valley and Great Lakes region eastward, the minimum temperatures in the interior portions of the Middle Atlantic States and over much of New England falling materially below freezing. Damaging frosts occurred in in these sections.

Decidedly cooler weather overspread the southern portions of the Rocky Mountain and Plateau regions on the 23d and 24th, when the lowest temperatures of the month occurred at points in Arizona and near-by States.

Near the end of April cool weather overspread most districts from the Rocky Mountains eastward and at the close the lowest temperatures of the month were prevailing in portions of the Great Plains.

The excess of temperature in April over so large a part of the North American Continent, the only exceptions being the extreme southern part of Florida and locally in the lower St. Lawrence Valley, coupled with similar conditions during February and March preceding, forms a three-month period of excess in temperature that, for extent of territory covered and amount of excess, has not been experienced in more than 50 years. The maximum temperatures reached or passed 90° in nearly all the States and exceeded 100° in some cases, the highest, 107°, occurring in Texas. The dates of highest readings were confined mainly to the latter part of the second and early part of the third decade, over the districts east of the Rocky Mountains, the 23d and 24th being particularly warm, when the readings over many sections east of the Mississippi and in the Southern Plains exceeded any previous record for April.

The lowest temperatures were observed mainly during the first few days of the month in the Southern and Central States, though they occurred on the 6th and 7th over portions of the Middle Atlantic States, on the 21st in New York and New England, and on the 28th to 30th over the Great Plains.

PRECIPITATION

The cyclones of the month were attended by unusually light precipitation as a rule and the accompanying precipitation areas were likewise small. As a result precipitation was deficient, as has been the case for several months, over much of the country from the Rocky Mountains eastward. This was particularly the case from the Mississippi River eastward, where the State averages were uniformly below the normal.

Between the Mississippi River and Rocky Mountains there were slight excesses in Missouri, Kansas, Oklahoma, and along the northern boundary, but deficiencies continued in the other States. West of the Rockies the precipitation was mainly slightly above the April average.

In the West Gulf States the deficiency was large and, as this condition had existed for several months, the need of more rain at the end of the month was very great, particularly along the coast. In Louisiana the precipitation was the least of record for April, and the three-months' period, February to April, inclusive, was likewise the driest of record. In Texas the long drought was

partly broken, but dry weather continued in New Mexico and Colorado where the lack of water is becoming serious.

In California favorable rains occurred over most of the State, and in some localities the month was decidedly rainy for the close of the wet season.

SNOWFALL

From the Rocky Mountains eastward the snowfall was confined to local small areas, though some unusual falls were reported.

In northern New York and New England one of the heaviest snowfalls of record occurred on the 19th and 20th, when depths up to 10 or 15 inches were reported. In portions of the upper Mississippi Valley and upper Lake region there were some unusual falls on the 28th and 29th.

In the western mountain districts more than the usual amount of snow occurred in California, but, on account of high temperatures, it soon melted at the lower elevations, and it is estimated the run-off from melting snow in that State will be exhausted earlier than usual.

In the other Mountain States there was less than the normal snowfall generally for April over New Mexico Colorado, and Utah, while to the northward the amounts were more nearly normal. In Montana an unusually heavy fall of snow occurred on the 23d over the southwestern and some western portions, some stations reporting as much as 20 inches or more.

RELATIVE HUMIDITY

Relative humidity was less than normal over nearly all portions of the country. This was partly due, no doubt, to the general excess of temperature. The atmosphere was unusually dry in portions of the Great Lakes, Gulf States, and Rocky Mountain regions.

SUNSHINE AND CLOUDS

There was a good percentage of sunshine in all parts of the country, save in the far Northwest, though in California and other parts of the Southwest the percentages of the possible were in many cases less than normal.

SEVERE LOCAL HAIL AND WIND STORMS, APRIL, 1925

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
East-central and southeastern Wyoming.	1-2				$25,000	High wind and snow.	Heavy damage to light and power lines	Wyoming Tribune Leader (Cheyenne, Wyo.). Official, U. S. Weather Bureau.
Vicksburg, Miss. (near)	3	P. m.				Hail	Considerable damage to fruit trees, truck, and windows.	Do.
Greenwood, Fla. (near)	4	2-3 p. m.	880		2,000	do	Corn stripped; cotton killed in places.	Do.
Miami, Fla. (near)	5	1-2 p. m.	100	5	300,000	Tornado and hail.	Severe damage to auto tops and other exposed property; minor damage to crops; 35 persons injured. Path 12 miles long.	Do.
Hilliard, Fla	6	3 p. m.	3-4 mi			Heavy hail	Vegetables and foliage injured	Do.
Clarksdale, Mo. (near)	7	5 p. m.		1		Thunderstorm	1 death by lightning; no property damage reported.	Do.
Perkins, Okla	8	2:30 p. m.				Tornado	Minor property damage	Do.
Addington Bend, Okla	8	3:30 p. m.			10,000	do	Considerable property damage	Do.
Madill, Okla	8	5:30 p. m.		1	5,000	do	3 persons injured; slight property damage	Do.
Caryville, Fla. (near)	8	3-4 p. m.				Heavy hail	Crops damaged but extent not known	Do.
Republic, Mo., and vicinity	8	7:15 p. m.	880		5,000	Severe hail	Damage chiefly to orchards	Do.
Parts of Grayson, Fannin, Lamar, and Titus Counties, Tex.	8	3-8 p. m.			66,000	do	Heavy damage to crops and buildings	Do.
Thackerville, Okla	8	4 p. m.	3 mi.			Heavy hail	Fruit total loss; crops suffer severely; 3,000 acres of corn will have to be replanted. Path 5 miles long.	Do.
Holdenville, Okla	8	4:15 p. m.			4,000	do	Fruit considerably injured	Do.
Dayton, Ohio, and vicinity	9	3:30 p. m.				Wind	General damage about the city and in the vicinity; 2 persons injured.	Herald (Dayton, Ohio).
Christian County, Ky. (eastern part of).	9	4 p. m.	1,760			Thunderstorm and hail.	Skylights and roofs in Pembroke damaged; loss of merchandise by rain. Other minor damage.	Official, U. S. Weather Bureau.
Ideal, Montezuma, Gresston and Buckhead, Ga.	10	12:30-2:15 p. m.			100,000	Heavy hail	Peach orchards, cotton, and corn severely damaged.	Do.
Central Calumet County, Wis.	10-11	About midnight.	Few—880		4,000	Tornado	Two barns and several outbuildings demolished.	Do.
Alva, Okla. (4 miles west of)	12	8:30 p. m.	3-7 mi.			Hail	Much damage to fruit	Do.
Springfield, Ill., and vicinity.	13	2 p. m.			16,000	High wind	Roofs, windows, signs, auto tops, etc., damaged; 8 persons injured.	Do.
Sullivan, Ind	13	5:30 p. m.				Tornadic wind	A number of buildings unroofed	Do.
Kokomo, Ind	13	6 p. m.				Tornado	About 12 houses unroofed; several barns moved	Do.
Plymouth, Ind. (near)	13	do				Wind	Several roofs torn off	Do.
St. Joseph County, Ind	13	P. m.			10,000	do	Considerable property damage	Do.
Ft. Wayne, Ind	13	7 p. m.				do	Damage to buildings throughout city	Do.
Carbondale, Kans	14	P. m.				Violent wind	Many porches blown off; trees wrecked	Do.
Condon, Oreg	15	P. m.			10,000	Small tornado	Much damage to warehouses and other buildings.	Do.
Chicopee, Mass	15					Tornadic wind	House and 5 garages destroyed	Hartford Times (Conn.).
Sunnyside, Wash., and vicinity.	16	4-4:15 p. m.	5 mi.		5,000	Heavy hail	Some crops damaged; windows broken	Official, U. S. Weather Bureau.
Howard County, Nebr	18	2 a. m.				Hail	Fruits and early vegetables injured; windows broken and roofs damaged.	Do.
South central and southeastern, Wis.	18	9 a. m. to midnight.				Heavy hail and severe squalls.	Silos blown down, buildings unroofed, plate glass windows broken. No damage by hail.	Do.
Long Creek, N. C	18	3-3:45 p.m.	1,760		2,000	Hail	Damage principally to strawberries. Path 6 miles long.	Do.
Dodge City, Kans. (near)	18	5 p. m.	2 mi.		8,000	Severe hail	Crops not sufficiently advanced to suffer much; auto tops injured; minor damage to other property.	Do.
Humboldt and Wright Counties to Winneshiek, Howard and Mitchell Counties, Iowa.	18					do	Damage consisted chiefly of broken windows, punctured roofs, and injured fruit.	Do.
Carroll County, Ill	18	P. m.				Hail and wind	Farm buildings damaged; roof blown from schoolhouse; minor damage at various points.	Do.

[1] Yards when not otherwise specified; "mi." signifies miles.

Severe local hail and wind storms, April, 1925—Continued

Place	Date	Time	Width of path	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Bruning, Nebr	18	8 p. m.	1,760			Hail	Fruit and vegetables injured	Official U.S. Weather Bureau.
Quincy, Ill	19	2:05 a. m			5,000	do	Greenhouses damaged and fruit blossoms injured.	Do.
Peoria, Ill., and vicinity	19	3:03 a. m		2	500,000	High wind and electrical.	Four-story building blown over; minor damage to roofs and trees.	Do.
Richland County, Wis	19	5-8 a. m	25 mi.			Heavy hail	No extensive damage, as crops were not far enough advanced to be injured.	Do.
Toledo, Ohio, and vicinity	19	9-10 a. m				Wind and hail	Damage principally to greenhouses	Do.
Pekin, Ill	19				60,000	High wind	Extensive damage in business section	Do.
Canton, Ill	19				10,000	do	Character of damage not reported	Do.
West Virginia (northern part of).	19	12:04-2:15 p. m.			300,000	Thunderstorm, wind, and hail.	Storm most severe at Wheeling: 1 building unroofed, others damaged; oil derricks blown down; many fruit trees uprooted.	Do.
Greensburg, Pa., and vicinity	19	12:45 p. m.	500		15,000	Small tornado	Railroad station at Wyano destroyed, several houses unroofed, trees blown down at Irvin and Scottdale.	Do.
Pittsburgh, Pa., and vicinity	19	1 p. m.			800,000	High wind and heavy rain.	Small houses unroofed; several persons injured by flying glass.	Do.
Newell and California, Pa., and vicinity.	19	1-1:25 p. m	300		10,000	Small tornado	Loss confined to buildings; 6 persons injured	Do.
Cresson, Pa	19	1:30 p. m			45,000	High winds and rain,	Church partly demolished and a building under construction blown down.	Do.
Garrett to Frederick County, Md.	19	1-3 p. m			50,000	Wind	Poles, silos, and fences down; trees uprooted; buildings damaged; 2 persons injured.	Do.
Philipsburg, Pa	19	2:15 p. m	500		3,000	Small tornado	Considerable damage to trees, buildings, etc., and slight crop damage.	Do.
Belleville, Pa., and vicinity	19	2:30 p. m	200		150,000	Tornado	Flour mills blown down and burned; roofs of many buildings blown off and considerable minor damage.	
Tonkawa, Okla	19	2:30 p. m	6 mi.		350,000	Hail	Crops practically ruined; roofs badly damaged. Path 12 to 15 miles long.	Do.
State College, Pa	19	2:45 p. m	800			High wind and rain.	Damage mostly to trees; a few buildings unroofed and some small outbuildings demolished; 2 persons injured.	Do.
Sykesville, Pa., and vicinity	19	P. m			40,000	do	Houses unroofed; power plant at Fayette out of commission.	Do.
Shakertown to Lexington, Ky.	19	4 p. m	1-2 mi.			Thunderstorm and and hail.	Tobacco-plant buds injured. Patch 25 miles long.	Do.
White Cloud, Kans	20	P. m				Heavy hail	Crops not far enough advanced to be hurt	Do.
Pawnee County, Nebr	20	4 p. m				Small tornado and hail.	Several small farm buildings unroofed; trees uprooted.	Do.
Frederick, Okla., and vicinity.	20	4:45-5:15 p. m.			75,000	Severe hail	Heavy roof and glass damage. Crop damage not estimated.	Do.
Falls City, Nebr	20	6-7 p. m	16 mi.		150,000	Hail	Fruit, small grains, and alfalfa considerably damaged; some windows broken.	Do.
Napier, Mo	20	8 p. m	880			do	Windows broken; roofs damaged; gardens and fruit suffered.	Do.
Chillicothe, Mo	20	do				Thunderstorm squall.	Houses unroofed; silos blown down; other minor damage.	Do.
Sylvania, Ga	21	12:05-1:30 a. m.	2 mi.		10,000	Hail and wind	Many trees and outhouses blown down; cotton and corn destroyed over wide area.	Morning News (Savannah, Ga.).
Oak Grove, Okla	21	1 a. m	880-1,760			Heavy hail	Heavy damage; crops severely injured. Path 5 to 6 miles.	Official, U. S. Weather Bureau.
Quartzsite, Ariz	21					Hail	Fruit, melons, and garden truck destroyed	Do.
White Hall, Ill	21					do	Roofs, greenhouses, and auto tops damaged	Do.
Richmond, Ind., and vicinity	21					Heavy hail	Chief damage to gardens and greenhouses	Do.
Appanoose County, Iowa	21					Wind and hail	Barns and silos wrecked	Do.
Dundy, Hitchcock, and Red Willow Counties, Nebr.	22	6:30-8:30 a. m.				High wind	Many small buildings demolished, barns unroofed, and chimneys blown down; 2 persons injured.	Do.
Dane, Bank, and Milwaukee Counties, Wis.	22	9:30-10:30 a. m.	3-5 mi.		50,000	Heavy hail	Damage to all greenhouses in and near Milwaukee.	Do.
Mitchell, Norton, and Phillips Counties, Kans.	22	1 p. m				Violent wind	Damage chiefly to windmills and outbuildings	Do.
Madison, Polk, Wheeler, and York Counties, Nebr.	22	7-8 p. m				High wind	Numerous windmills, barns, and small buildings wrecked.	Do.
Chase and Morris Counties, Kans.	23	2-3 p. m	300-400		12,000	Tornado	Storm passed over mostly sparsely settled community. Some barns and garages damaged.	Do.
Atchison, Kans	23	4 p. m.				do	Trees and chimneys wrecked, roofs damaged; 2 persons injured.	Do.
Central Michigan, from St. Louis to Bay City.	24				250,000	do	Heavy property damage	Do.
Quincy, Ill	24	10:15 a. m			5,000	Hail	Fruit trees and gardens damaged	Do.
Seymour, Mo. (northeast of)	24	P. m			2,000	Thunderstorm	Barn and contents destroyed	Do.
St. Charles and Kane Counties, Ill.	24	3 p. m				Hail	Many windows broken	Do.
Waukegan, Ill	24	2:50 p. m				Hail and wind	Damage principally to windows	Do.
Racine County, Wis	24	P. m			1,000	Wind and hail	Barns, sheds, and trees blown down. No damage by hail.	Do.
Perry, Mo. (near)	25	1:15 p. m		1		Thunderstorm	One death by lightning. No damage reported	Do.
Dallas, Tex., and vicinity	25-26					Thunderstorm and wind.	Considerable property damage in the vicinity reported.	Do.
Pauls Valley, Okla	26	4:50-5:15 p. m.	3-5 mi.			Heavy hail	Extensive damage; some cattle injured	Do.
Kyle, Tex	28	6 p. m	4 mi.	3	100,000	Wind and hail	Several buildings destroyed, others unroofed; 25 persons injured. Path 15 miles long.	Do.
Rockingham, N. C	28	1 p. m.				Hail	Several hundred acres of cotton destroyed; probably some damage to peach crop.	Do.
Robeson and lower Cumberland Counties, N. C.	28	P. m.				do	Cotton damaged to some extent; tobacco plants injured.	Do.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

No severe storms crossed the Washington Forecast District during the month, and storm warnings were required on only three occasions. Small-craft warnings were displayed on six days and they were mostly for the coast from Cape Hatteras northward. None were displayed along the east Gulf coast.

The first storm warnings displayed were from Delaware Breakwater to Eastport, Me., in connection with a disturbance of considerable intensity that was central over northern Indiana on the morning of the 19th. This disturbance was moving eastward underneath a very slowly moving high-pressure area that was over Ontario and Quebec at that time. The highest wind velocity reported was 60 miles an hour from the northeast at Nantucket, Mass.

On the morning of the 28th a disturbance of moderate intensity was central over eastern Tennessee, while an area of high pressure of considerable strength was over the Lake region and Ontario, and both were moving slowly eastward. Northeast storm warnings were ordered displayed from Cape Hatteras to Boston at 9.30 a. m. The highest velocity reported was 48 miles an hour from the northeast at Cape Henry, Va.

The last storm warnings of the month were displayed from Block Island, R. I., to Eastport, Me., at 9 a. m. of the 30th, in connection with a widespread disturbance over the eastern half of the United States and a strong high-pressure area over the Canadian Maritime Provinces. Block Island, Nantucket, and Eastport reported velocities in excess of 40 miles an hour, the highest being 48 miles from the northeast.

On account of the rather warm weather during much of April, fewer frost warnings than usual were required. Frost was reported from quite limited areas, mostly in the Ohio Valley, the middle Atlantic States, or the Appalachian region, on the 2d, 4th, 7th, 8th, 16th, 17th, 21st, and 29th. Frost warnings were not required at the end of the month for the greater part of New England and New York.—*C. L. Mitchell.*

CHICAGO FORECAST DISTRICT

Storm warnings.—The storm-warning season on the Great Lakes opened on the 16th, but prior thereto one advisory warning for the benefit of shipping on Lake Michigan was issued. This was on the night of the 12th, in connection with a disturbance over North Dakota that increased considerably in energy as it crossed the Lake region. However, no verifying velocities were reported from Lake Michigan stations.

Four disturbed periods occurred after the 16th, and warnings were issued for the various portions of the Great Lakes, as indicated in the following paragraphs:

On the 18th warnings were displayed on all the Great Lakes. Most of the advices were issued from the evening map of that date when a disturbance of rapidly increasing strength, with a central pressure of 29.36 inches, was over southeastern Iowa. At the same time a high-pressure area covered most of Ontario. This storm took an almost due eastward course into the Atlantic Ocean. In most of the southern half of the Lake region the wind reached gale force, and over at least limited sections the storm was rather severe. An accompanying feature was the widespread occurrence of thunderstorms.

Small-craft warnings were advised on the 21st for Lakes Michigan, Huron, and Erie in connection with a disturbance of considerable depth over the southern Rocky Mountain region and a marked high-pressure area over the St. Lawrence Valley and the Eastern States. The gradient decreased during the day and no verifying velocities occurred.

Another disturbed period covered the 23d–24th, and either storm or small-craft warnings were issued for most of the Upper Lake region. The disturbance was of considerable depth when it reached Manitoba in its eastward course, but filled in thereafter. For the most part the warnings were justified.

The final disturbance of the month covered the last two days. Warnings were displayed on Lakes Michigan, Huron, and Erie and extreme western Lake Superior. This disturbance developed over the Great Plains and the center passed south of the Lakes. The storm was not severe at any point, but verifying velocities were reached over most of the region where the displays were made.

Frost warnings.—Owing either to the prevailing mildness or because vegetation in most northern portions of the forecast district had not attained the stage of being susceptible to frost, but few frost warnings were issued until the last week of the month. At the beginning of the month warnings were being issued, as deemed necessary, only for the extreme southern portion of the district. Two weeks later vegetation was susceptible to frost damage as far north as Iowa, while the latter half of the month witnessed the spread of this phenomenon to all the remainder of the district except upper Michigan. From the 26th to the close the weather was cool and frosty, especially in the Plains region, where heavy-to-killing frosts or freezing temperatures were almost of nightly occurrence. The warnings issued at this time were for the most part verified.

Special forecasts.—The special long-range forecasts for the benefit of fruit interests in southwestern Michigan were resumed for the season on April 1, and two days later was begun the sending of fire-weather forecasts for northeastern Minnesota to the State forester at St. Paul, Minn.—*C. A. Donnel.*

NEW ORLEANS FORECAST DISTRICT

During the greater part of the month this district was under the influence of sluggish Rocky Mountain troughs of low pressure, with but brief interruptions when moderate HIGHS dominated conditions. However, a well-defined area of high pressure, advancing from the northern Rocky Mountain States during the closing days of April, was attended by the lowest temperatures of the month at many stations, although no freezing weather was recorded at the regular stations.

No storm warnings were issued or needed. Small-craft warnings were displayed on the Texas coast on the 21st, 22d, and 29th and were justified.

Frost warnings for northern areas in the district were issued on the 4th, 9th, 29th, and 30th and were generally justified. No damaging or extensive frosts occurred.

Fire-weather warnings were issued for forest areas in Arkansas and Oklahoma on the 2d and Oklahoma and Texas on the 22d. Wind and weather occurred as forecast. There was a marked deficiency of precipitation for the month and the fire hazard was greater than is usual for the season.—*R. A. Dyke.*

DENVER FORECAST DISTRICT

A disturbance that was central over western Colorado on the morning of the 1st moved southeastward at a uniform rate, followed by showers over Utah and western and northern Colorado. The next disturbance affecting this district approached the Washington coast on the morning of the 2d; by the morning of the 3d it was well defined in southern Nevada. It then pursued a more or less halting course across the district, reaching eastern Colorado on the 5th, when it abruptly changed direction and dropped southward into New Mexico and the Texas Panhandle, where it remained about stationary until the evening of the 8th and then moved rapidly northeastward. Precipitation accompanying this storm did not begin in this district until the night of the 4th. Thereafter it occurred very irregularly, both as to time and geographical distribution, mostly over Utah and Colorado, until the morning of the 9th.

On the evening of the 4th, when the center of the storm was over Utah and it seemed certain that it would move eastward across northern Colorado, and in view of the serious fire hazard known to exist in the forests, a warning of fresh to strong southerly winds Sunday in Colorado was issued and the district forester's office at Denver notified. This warning was fully justified. The week from the 9th to the 16th was characterized by mostly high barometric pressure north and northwest of the district and moderately low pressure over the southwest, a condition resulting in fair, mild weather for the whole district. By the evening of the 15th the southwestern LOW became active and took a northerly course to northeastern Colorado, where it was centered on the evening of the 17th, thereafter moving eastward without causing precipitation in this district.

The most important disturbance of the month developed in southwestern Utah during the night of the 18th; it then spread out over most of the Plateau and southern Rocky Mountain districts, where it remained for several days, most of the time with two or three separate LOW centers, first one and then another of which would appear predominant. The whole system assumed a definite conformation, with a center over southeastern Wyoming on the evening of the 22d, and thereafter pursued a most abnormal course north-northwestward to north-central Montana and thence eastward and northeastward into Canada. The northward tendency of this disturbance was foreshadowed on the 21st by an abrupt cooling, accompanied by heavy precipitation, in Arizona. The precipitation accompanying this storm prior to this date was very light and confined mostly to Utah. On the evening of the 22d a warning of fresh westerly winds in eastern Colorado for the following day was issued and the Forest Service notified. Fairly high winds occurred in northeastern Colorado. During the last five days of the month low pressures prevailed generally over the southwest, but there was no really active storm center.

On the 27th an unusually strong anticyclone that had occupied the British Columbia coast for about two days began to drift rapidly southeastward. By the morning of the 28th it was centered in southeastern Montana, had increased in intensity, and was moving very rapidly southeastward; it then took a more southerly course and reached well into Texas by the morning of the 29th, causing a rather severe freeze in northeastern Colorado, and a very sharp temperature fall in eastern New Mexico. The freeze in Colorado was covered by a warning issued on the morning of the 28th of frost for the State, with freezing temperature in the northeast portion. Other frost and freezing temperature warnings, nearly all of which were followed either by frost or the occurrence of temperatures low enough for its formation, were issued as conditions seemed to require, and in nearly all parts of the district at one time or another on 19 mornings throughout the month.—*E. B. Gittings, jr.*

SAN FRANCISCO FORECAST DISTRICT

The month opened with an unsettled, rainy condition over the northern and central portions of this district during the first five days, which extended into southern California and southern Nevada on the 4th, 5th, and 6th. Light rain again occurred from central California northward on the 11th and in western Washington on the 12th. A prolonged period of unsettled and rainy weather prevailed over the central and northern portions of this district from the 15th to the 22d. The rainfall during this period was quite heavy in the San Joaquin Valley and portions of southern California and was of great benefit to all agricultural and horticultural interests. It brought the seasonal rainfall in the San Joaquin Valley to about the normal and in southern California to about one-half the normal to date.

From the 7th to the 10th and from the 12th to the 15th fair and quite warm weather prevailed over the entire district. In eastern Washington it was especially warm, and the record for high temperature in April was broken at Walla Walla on the 9th.

Heavy frosts occurred in eastern Washington and eastern Oregon on the 20th and 21st, and heavy to killing frosts in Nevada, Idaho, eastern Washington, and eastern Oregon from the 24th to the 28th. Frost warnings were issued during these periods in the districts affected.

Storm warnings were issued from Marshfield to Tatoosh Island on the 1st, 2d, and 18th, and from Port San Luis to San Diego on the 4th.

Forecasts for the fruit-frost service at Medford, Oreg., and at stations in eastern Washington were commenced on the 10th.

Warnings of expected high seas were issued to the United States Engineers working on the jetty at the entrance of Humboldt Bay on the 2d, 17th, 27th, 29th, and 30th.—*G. H. Willson.*

RIVERS AND FLOODS

By Robin E. Spencer

As will be noted in the table below, the few floods of April, 1925, were widely scattered and of little magnitude. The Connecticut River flood, which was discussed in the March number of this Review, continued for a few days in April without further reported damage; and the rises in the White River of Arkansas, the Grand River of Missouri, the Rio Grande, and the Trinity and Willamette rivers, for all of which warnings were issued in time to save any jeopardized property except small areas of lowland crops, were without damage of consequence. As the flood in the Sulphur River attained its greatest importance below Ringo Crossing, Tex.,

and after the close of the month, it will be discussed in the May issue of this REVIEW.

River and station	Flood stage	Above flood stages—dates From—	Above flood stages—dates To—	Crest Stage	Crest Date
ATLANTIC DRAINAGE					
Connecticut:	*Feet*			*Feet*	
White River Junction, Vt	15	(1)	2	22.5	Mar. 29
Holyoke, Mass	9	(1)	(2)	9.4	31
Hartford, Conn	16	(1)	3	20.5	Apr. 1
MISSISSIPPI DRAINAGE					
Illinois:					
Henry, Ill	7	(1)	9	9.6	Mar. 24, 25, 26
Havana, Ill	14	(1)	2	14.3	27-30
Beardstown, Ill	12	(1)	14	15.4	28, 29
White:					
Calico Rock, Ark	18	28	29	20.5	28
Batesville, Ark	23	29	30	25.6	29
Sulphur: Ringo Crossing, Tex	20	11 27	12 (3)	20.5 23.4	12 28
Grand:					
Gallatin, Mo	20	25	25	21.0	25
Chillicothe, Mo	18	25	27	24.5	26
Brunswick, Mo	10	27	29	10.0	27-29
WEST GULF DRAINAGE					
Trinity: Dallas, Tex	25	27	27	[4] 25.3	27
Rio Grande: San Marcial, N. Mex	2	18	24	2.4	20
PACIFIC DRAINAGE					
San Joaquin: Friant, Calif	8	13 27	18 30	9.1 8.9	17 29
Willamette: Portland, Oreg	15	20	24	15.6	22

[1] Continued from last month.
[2] Continued at end of month.
[3] Below flood stage at 8 a. m. Apr. 1.
[4] Estimated.

MEAN LAKE LEVELS DURING APRIL, 1925

By UNITED STATES LAKE SURVEY

[Detroit, Mich., May 6, 1925]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes [1] Superior	Michigan and Huron	Erie	Ontario
Mean level during April, 1925:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	600.85	578.50	571.35	245.61
Above or below—				
Mean stage of March, 1925	+0.05	+0.12	+0.44	+0.41
Mean stage of April, 1924	−0.16	−0.39	−0.42	+0.25
Average stage for April, last 10 years	−0.86	−1.65	−0.83	−0.39
Highest recorded April stage	−1.84	−4.73	−2.83	−2.82
Lowest recorded April stage	+0.31	−0.39	−0.29	+0.77
Average relation of the April level to—				
March level		+0.3	+0.6	+0.6
May level		−0.3	−0.4	−0.4

[1] Lake St. Clair's level: In April, 1925, 573.76 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, APRIL, 1925

By J. B. KINCER

General summary.—As a result of the generally mild and mostly fair weather that prevailed during April, both vegetation and farm work advanced rapidly for the season and were considerably ahead of an average year, except in the Southwest where the soil was too dry for planting and for germination and growth. There was some frost damage to fruit and tender vegetation in limited areas, but harm was not extensive. In the Southeast, during the latter part of the month, late-seeded crops needed showers for best germination, but the early seeded were generally doing well. In the great western range sections the weather was favorable for the range and livestock from the central and northern Great Plains westward, but severe drought prevailed in the South, especially in the southern border States where a large portion of the range was poor and in many places bare, with considerable loss of livestock.

Small grains.—The month, on the whole, was favorable for winter and spring grains in the interior and Central-Northern States. The seeding of oats and spring wheat had been largely completed at the close of the month and germination was satisfactory. Winter wheat improved steadily, especially in the western portion of the Winter-Wheat Belt where rainfall was of great benefit. This crop was spotted, however, in parts of the Ohio Valley and the general condition continued poor in the upper valley districts.

Corn.—Considerable corn was planted in the central valley States the last part of the month and seeding was begun in the Great Plains as far north as central Nebraska. Corn was germinating satisfactorily, except where it was too dry in parts of the South, principally in the Southwest, though rain during the closing days of the month furnished needed moisture in these sections. An unusually large amount of corn ground was prepared early this year as a result of the favorable weather for outdoor operations.

Cotton.—Favorable weather prevailed for planting cotton and for germination of seed in the central and eastern portions of the belt; early cotton came up generally to a good stand. In the West the drought further delayed planting especially in Texas, and early-planted cotton made poor progress, except in local areas. Near the close of the month, however, the drought was relieved by generous rains which materially improved the outlook and planting was pushed vigorously, but in the meantime the lack of moisture was beginning to be felt in central and eastern cotton States. The last days of April were much too cool for cotton in all parts of the belt, the low temperatures being decidedly unfavorable for germination of late plantings.

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, April, 1925

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	68.2	+4.8	Florence	96	[2] 23	2 stations	31	[2] 1	1.51	−2.94	Florence	3.68	2 stations	0.10
Alaska (*March*)	24.3	+0.3	Sitka	57	9	Allakaket	−57	27	4.29	+0.83	Fortmann Hatchery	14.98	Eagle	0.17
Arizona	60.8	+2.2	Gila Bend	106	14	Fort Valley	6	24	0.77	+0.18	Crown King	3.75	3 stations	0.00
Arkansas	67.4	+6.2	2 stations	98	[2] 15	Gravette	28	30	2.62	−2.16	Eureka Springs	7.15	Portland	0.00
California	56.2	+0.2	Needles	106	14	Helm Creek	−13	1	2.85	+1.16	Upper Mattole	14.63	Bagdad	0.00
Colorado	47.0	+4.2	Las Animas	91	17	Cathedral	7	8	0.64	−1.43	Savage Basin	2.76	Penrose	0.00
Florida	70.3	+0.4	2 stations	95	[2] 20	Arcadia	34	2	1.54	−1.25	Hypoluxo	5.10	Lynne (near)	0.15
Georgia	67.5	+4.1	3 stations	99	24	Clayton	26	1	1.72	−1.84	Montezuma	3.75	Alapaha	0.54
Hawaii	69.4	−0.5	Waialua Mill	89	22	Waimea	45	15	8.83	+0.02	Waiakamoi Gulch	50.30	2 stations	0.60
Idaho	47.5	+2.7	Orofino	86	[2] 10	Obsidian	6	20	1.70	+0.31	Council	4.04	St. Maries	0.07
Illinois	58.6	+6.8	Flora	94	23	Pana	21	1	2.66	−0.75	Elgin	5.26	Paris	1.02
Indiana	57.3	+5.6	Scottsburg	96	24	4 stations	22	[2] 2	2.26	−1.21	Salamonia	4.38	Goshen	0.83
Iowa	56.5	+7.6	Waterloo	95	22	Postville	21	5	2.20	−0.79	Centerville	5.34	Allison	0.71
Kansas	59.8	+6.2	Medicine Lodge	97	20	2 stations	22	[2] 29	3.52	+0.92	Toronto	8.74	Leoti	0.52
Kentucky	61.2	+5.3	Farmers	98	24	Farmers	23	1	3.17	−0.86	Junction City	6.70	Grayson	1.24
Louisiana	70.7	+3.9	2 stations	95	[2] 15	Minden	36	30	1.00	−3.72	Lafayette	2.96	2 stations	0.00
Maryland-Delaware	55.2	+2.7	do	97	24	2 stations	20	7	2.55	−0.77	Oakland, Md	3.88	Solomons, Md	1.27
Michigan	47.3	+5.0	Mount Clemens	94	23	Humboldt	7	5	1.88	−0.47	Alma	4.48	Humboldt	0.15
Minnesota	49.0	+6.5	Pipestone	89	12	Pine River Dam	6	5	2.10	+0.02	Bemidji	5.06	Grand Marais	0.50
Mississippi	69.3	+5.2	3 stations	95	[2] 16	Batesville	33	1	1.15	−4.26	Grenada	4.33	Collins	0.00
Missouri	61.0	+5.9	2 stations	92	[2] 10	Downing	24	5	4.11	+0.38	Milan	8.14	Hannibal	1.90
Montana	46.7	+4.5	Medicine Lake	88	10	Babb	9	25	1.85	+0.81	Red Lodge	6.07	Fortine	0.30
Nebraska	55.2	+6.2	Kearney	94	22	Harrison	13	29	2.38	−0.06	Guide Rock	5.35	Ainsworth	0.52
Nevada	50.3	+1.7	Logandale	98	13	Gerlach	14	2	1.38	+0.61	Mahoney Ranger Station.	4.18	Quinn River Ranch	0.03
New England	45.2	+1.9	Fitchburg, Mass	85	26	Cavendish, Vt	6	21	2.14	−1.08	Somerset, Vt	4.34	Rumford, Me	0.62
New Jersey	51.4	+2.1	2 stations	88	23	Runyon	15	7	2.40	−1.22	Indian Mills	3.35	Boonton	1.31
New Mexico	55.0	+4.2	Carlsbad	100	16	Vermejo Park	−3	2	0.14	−0.95	Pearl	0.99	30 stations	0.00
New York	46.3	+2.0	Addison	92	24	Indian Lake	5	21	2.51	−0.29	Gloversville	4.36	Chazy	0.52
North Carolina	61.4	+3.5	Rockingham	99	24	Parker	18	2	2.44	−1.34	Parker	4.28	Shelby	0.70
North Dakota	47.8	+6.1	5 stations	85	[2] 10	Hansboro	10	29	1.64	+0.26	McLeod	4.24	Eckman	0.63
Ohio	54.2	+4.2	Portsmouth	97	24	2 stations	21	6	2.04	−1.23	Tippecanoe City	5.57	Youngstown	0.71
Oklahoma	66.1	+6.6	2 stations	102	[2] 18	Goodwell	27	29	4.50	+1.12	Union City	8.37	Kenton	0.68
Oregon	50.3	+2.6	Echo	91	9	Crater Lake	10	27	2.77	+0.55	Willow Creek	10.44	Andrews	0.55
Pennsylvania	51.3	+2.5	4 stations	96	24	West Bingham	9	6	2.32	−1.02	Somerset	4.89	Renovo	0.93
Porto Rico	75.4	+0.2	Comerio Falls	95	4	2 stations	51	13	6.37	+1.62	Toro Negro	13.36	Vieques Sugar Co	0.25
South Carolina	65.9	+3.7	2 stations	99	[2] 24	Walhalla	25	1	2.12	−0.92	Paris Island	5.41	Little Mountain	0.85
South Dakota	52.7	+7.6	Forestburg	90	12	Elk Mountain	14	28	1.63	−0.44	Mellette	3.67	2 stations	0.51
Tennessee	63.6	+5.2	Etowah	98	24	Sevierville	23	1	3.34	−1.15	Liberty	6.77	Memphis	0.89
Texas	71.4	+5.4	3 stations	107	18	Lieb (near)	28	6	2.06	−1.19	Denison	8.46	7 stations	0.00
Utah	48.6	+2.2	St. George	91	[2] 14	2 stations	13	1	1.23	−0.04	Silver Lake	3.99	Duchesne	T.
Virginia	57.2	+2.7	Hopewell	100	25	Ashland	17	7	2.60	−0.73	Mount Weather	5.21	Randolph	1.62
Washington	50.7	+2.5	3 stations	89	[2] 9	Republic	21	28	2.06	−0.13	Palmer	6.58	Granger	0.16
West Virginia	54.9	+3.4	Martinsburg	101	24	Cheat Bridge	6	3	2.80	−0.80	Sharples	4.48	New Cumberland	1.42
Wisconsin	49.0	+5.6	2 stations	90	22	Long Lake	3	5	2.10	−0.41	West Bend	4.75	Ashland	0.89
Wyoming	44.4	+4.4	Torrington	83	22	Dome Lake	−3	28	1.76	+0.14	Sheridan Field Station.	5.83	Dubois	0.15

[1] For description of tables and charts, see REVIEW, January, 1925, page 42.
[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1925*

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dewpoint	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
New England							**45.8**	**+1.9**										**70**	**1.99**	**−1.1**										**4.7**		
Eastport	76	67	85	29.88	29.97	+.04	39.8	+0.8	65	27	47	23	20	32	27	36	32	80	1.53	−1.4	12	8,179	nw.	45	ne.	30	10	8	12	5.6	4.4	0.0
Greenville, Me	1,070	6		28.81	30.00		39.0		72	26	50	12	13	28	39				1.46		8		nw.				11	7	12		7.0	
Portland, Me	103	82	117	29.89	30.02	+.06	45.2	+2.2	78	26	54	25	20	37	31	39	32	65	2.54	−0.6	9	7,616	nw.	34	s.	14	14	8	8	4.4	10.7	0.0
Concord	288	70	79	29.69	30.01	+.02	45.6	+2.2	79	26	56	24	17	35	40				1.99	−0.8	8	3,732	nw.	18	sw.	15	17	10	3	3.3	11.2	0.0
Burlington	404	11	48	29.59	30.04	+.05	42.8	−0.5	76	26	52	21	5	34	37				1.66	−0.2	10	8,022	n.	58	s.	14	10	7	13	5.4	7.1	0.0
Northfield	876	12	60	29.06	30.03	+.04	40.6	+0.3	76	26	53	8	21	28	44	37	32	70	1.68	−0.4	10	5,448	n.	32	se.	14	5	13	12	6.2	16.8	0.0
Boston	125	115	188	29.87	30.01	+.04	49.8	+3.4	82	26	58	31	21	41	29	43	36	64	2.48	−1.1	8	7,756	nw.	29	w.	15	11	13	6	4.6	T.	0.0
Nantucket	12	14	90	29.98	29.99	+.02	45.8	+2.4	72	26	52	32	20	39	23	42	38	80	2.37	−0.3	12	12,925	sw.	59	ne.	20	15	7	8	4.3	0.4	0.0
Block Island	26	11	46	29.97	30.00	+.02	46.4	+2.4	72	26	52	31	6	40	23	42	38	77	1.68	−1.9	10	12,778	sw.	53	ne.	20	15	8	7	4.3	T.	0.0
Providence	160	215	251	29.83	30.01	+.03	48.8	+2.2	82	26	58	29	6	39	32	41	33	59	1.95	−1.8	9	8,938	nw.	44	nw.	27	10	14	6	4.6	T.	0.0
Hartford	159	122	140	29.84	30.01	+.02	49.4	+2.7	82	26	60	29	21	39	34				1.97	−1.6	9		sw.				12	13	5	4.3	T.	0.0
New Haven	106	74	153	29.91	30.03	+.04	50.0	+2.8	83	23	59	30	21	41	36	43	37	66	2.06	−1.5	8	7,380	n.	34	n.	19	12	11	7	4.4	T.	0.0
Middle Atlantic States							**54.0**	**+2.7**										**69**	**2.46**	**−0.6**										**5.0**		
Albany	97	102	115	29.92	30.03	+.03	48.2	+1.4	81	26	58	28	6	38	37	42	36	66	3.16	+0.8	11	6,286	s.	42	s.	14	17	7	6	4.0	0.4	0.0
Binghamton	871	10	84	29.08	30.02	.00	48.2	+2.8	88	24	60	21	6	36	39				3.13	+0.9	8	4,393	nw.	40	nw.	25	10	9	11	5.2	1.0	0.0
New York	314	414	454	29.68	30.02	+.02	51.2	+1.8	83	23	60	32	21	42	36	44	36	63	1.73	−1.6	7	11,492	n.	72	nw.	15	6	15	9	5.7	T.	0.0
Harrisburg	374	94	104	29.64	30.04	+.02	53.3	+2.4	86	24	63	31	6	43	32	45	37	60	2.06	−0.4	11	5,357	ne.	35	w.	19	11	8	11	5.4	T.	0.0
Philadelphia	114	123	190	29.91	30.04	+.03	54.9	+2.8	84	23	64	34	21	46	34	47	41	65	2.43	−0.5	13	7,266	sw.	27	n.	8	13	9	8	4.8	0.0	0.0
Reading	325	81	98	29.68	30.04		52.6		84	23	63	31	21	43	32	47	42	70	3.10	−0.1	13	4,143	nw.	22	se.	13	15	6	9	4.4	T.	0.0
Scranton	805	111	119	29.16	30.04	+.03	49.4	+1.3	84	24	60	26	21	38	35	44	40	74	1.55	−1.1	8	5,234	nw.	37	sw.	15	10	12	8	5.2	0.3	0.0
Atlantic City	52	37	172	29.96	30.02	+.02	51.0	+3.2	83	27	58	33	21	44	26	46	42	75	2.68	−0.3	11	13,378	ne.	53	ne.	29	15	6	9	4.4	0.0	0.0
Cape May	17	13	49	30.03	30.05	+.06	52.3	+3.9	85	27	60	31	21	44	28	47	44	79	3.26	+0.3	14	6,532	ne.	30	w.	15	14	6	10	4.8	0.0	0.0
Sandy Hook	22	10	55	30.00	30.02		50.4		79	23	58	35	21	43	32	44	38	68	2.69		9	10,490	s.	47	nw.	13	9	13	8	5.1	0.0	0.0
Trenton	190	159	183	29.82	30.03		51.8		82	26	62	30	21	41	36	46	40	68	2.35	−0.9	11	7,636	n.	34	ne.	20	7	13	10	5.8	0.0	0.0
Baltimore	123	100	113	29.89	30.02	+.01	56.4	+2.8	88	23	66	34	21	47	36	48	41	62	2.66	−0.6	11	4,708	ne.	22	ne.	20	10	12	8	4.8	0.0	0.0
Washington	112	62	85	29.90	30.02	.00	56.9	+3.6	94	24	68	32	7	46	40	48	41	62	2.44	−0.8	10	5,160	s.	37	nw.	15	11	10	9	5.1	0.0	0.0
Cape Henry	18	8	54	29.98	30.00		57.2		97	25	65	42	4	50	36	52	49	80	2.52	−1.4	10	10,320	ne.	52	ne.	29	12	10	8	5.1	0.0	0.0
Lynchburg	681	153	188	29.27	30.02	.00	59.6	+2.3	95	24	72	31	7	47	44	51	45	65	2.61	−0.6	8	5,543	w.	37	w.	19	12	12	6	5.0	0.0	0.0
Norfolk	91	170	205	29.93	30.03	+.02	59.2	+2.4	92	25	68	40	3	50	31	52	48	74	1.74	−2.0	10	9,582	ne.	48	nw.	26	11	10	9	5.2	0.0	0.0
Richmond	144	11	52	29.87	30.03	+.01	59.2	+2.6	96	25	71	34	7	48	39	51	46	68	2.33	−1.1	10	6,211	ne.	38	nw.	26	13	11	6	4.6	0.0	0.0
Wytheville	2,304	49	55	27.65	30.01	−.02	56.0	+4.0	89	24	68	26	7	44	42	48	42	66	2.14	−1.5	10	4,479	w.	36	w.	25	9	9	12	5.4	T.	0.0
South Atlantic States							**64.7**	**+2.9**										**71**	**2.01**	**−1.2**										**4.4**		
Asheville	2,255	70	84	27.68	30.01	−.02	58.4	+4.5	89	24	70	30	1	47	36	49	43	66	2.45	−0.8	9	5,609	nw.	32	se.	21	14	10	6	4.3	0.0	0.0
Charlotte	779	55	62	29.18	30.01	−.02	63.9	+4.1	96	24	75	34	1	53	32	55	49	65	2.34	−1.1	6	3,283	ne.	22	nw.	26	13	8	9	4.8	0.0	0.0
Hatteras	11	11	50	30.00	30.00	−.01	61.0	+1.2	81	24	68	44	3	55	24	57	55	85	1.34	−3.1	7	10,088	n.	44	ne.	20	12	12	6	4.6	0.0	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.61	30.01	−.02	62.0	+2.6	93	25	73	38	3	51	39	53	46	65	2.57	−0.9	11	5,835	ne.	29	w.	10	12	9	9	4.9	0.0	0.0
Wilmington	78	81	91	29.94	30.02	−.01	64.1	+2.1	93	24	74	40	1	54	37	57	54	77	1.16	−1.7	7	5,494	sw.	32	e.	20	15	8	7	4.1	0.0	0.0
Charleston	48	11	92	29.96	30.01	−.02	66.8	+2.3	92	27	75	41	1	59	27	60	57	77	1.89	−1.1	4	8,305	sw.	48	ne.	20	13	12	5	4.4	0.0	0.0
Columbia, S. C	351	41	57	29.63	30.01	−.02	66.8	+3.5	94	24	78	34	1	55	33	57	52	67	1.24	−1.6	4	5,118	s.	27	ne.	20	16	6	8	4.2	0.0	0.0
Due West	711	10	55	29.27	30.04		64.4		92	24	76	33	1	52	35				1.84		9	6,457	sw.	33	ne.	6	13	10	7	4.5	0.0	0.0
Greenville, S. C	1,039	113	122	28.91	30.00		64.1	+5.5	92	24	75	37	1	53	34	54	47	61	2.74		7	4,976	n.	34	w.	26	14	10	6	4.5	0.0	0.0
Augusta	182	62	77	29.80	29.99	−.04	67.7	+3.5	94	20	80	37	1	56	34	59	55	69	3.23	−0.3	6	4,319	nw.	36	n.	20	14	10	6	4.1	0.0	0.0
Savannah	65	150	194	29.94	30.01	−.02	68.2	+2.2	94	20	78	38	1	58	29	59	55	74	2.37	−0.6	6	8,929	s.	46	e.	21	15	9	6	3.9	0.0	0.0
Jacksonville	43	209	245	29.96	30.01	−.03	69.0	+0.3	88	20	77	42	1	61	24	61	56	70	1.54	−1.2	3	9,133	se.	44	ne.	6	15	8	7	4.1	0.0	0.0
Florida Peninsula							**72.8**	**−0.8**										**72**	**2.57**	**+0.4**										**4.3**		
Key West	22	10	64	29.96	29.98	−.04	74.4	−1.3	84	18	80	63	3	69	17	67	64	72	3.61	+2.3	6	7,084	e	34	nw	6	16	8	6	4.0	0.0	0.0
Miami	25	71	79	29.98	30.01		72.2	−2.0	86	29	79	47	2	65	29	65	62	72	3.02	+0.3	8	5,990	e.	24	w.	5	12	14	4	4.4	0.0	0.0
Tampa	35	79	87	29.96	30.00	−.06	71.9	+1.0	91	21	81	52	2	63	25	63	59	71	1.09	−0.8	5	4,650	w.	21	ne.	7	12	13	5	4.5	0.0	0.0
East Gulf States							**69.1**	**+4.3**										67	**1.34**	**−2.7**										**4.1**		
Atlanta	1,174	190	216	28.78	30.01	−.02	66.4	+5.4	93	24	76	39	1	57	25	56	49	60	1.17	−2.5	5	7,768	nw.	40	nw.	29	12	10	8	4.6	0.0	0.0
Macon	370	78	87	29.61	30.00	−.03	68.4	+4.5	94	24	80	35	1	56	35	57	50	58	1.77	−1.6	4	4,590	s.	26	ne.	6	16	9	5	3.9	0.0	0.0
Thomasville	273	49	58	29.71	30.01	−.02	69.7	+3.0	90	24	81	43	1	58	31	60	54	64	1.91	−1.7	5	3,302	sw.	19	sw.	10	12	9	9	4.8	0.0	0.0
Apalachicola	36	42	49	29.97	30.01		68.4		82	28	75	51	2	62	21	63	60	78	0.96		3	5,439	w.	31	ne.	6	22	6	2	3.0	0.0	0.0
Pensacola	56	149	185	29.96	30.02	−.04	69.1	+2.4	84	16	75	53	1	63	20	63	59	74	1.02	−2.1	3	8,525	s.	40	s.	4	13	12	5	4.3	0.0	0.0
Anniston	741	9	57	29.24	30.03	.00	66.4	+6.0	92	24	79	34	1	53	38				1.57	−2.1	7	3,654	nw.	21	se.	21	18	8	4	3.5	0.0	0.0
Birmingham	700	11	48	29.27	30.02	.00	68.2	+4.9	90	24	79	41	1	58	32	57	50	60	1.15	−2.5	7	4,679	s.	25	nw.	10	14	12	4	4.1	0.0	0.0
Mobile	57	125	161	29.95	30.01	−.01	70.0	+3.7	89	16	79	51	2	62	28	62	58	74	0.43	−3.9	4	7,182	s.	40	nw.	4	11	14	5	4.6	0.0	0.0
Montgomery	223	100	112	29.76	30.01	−.02	69.6	+4.3	91	24	80	46	2	59	31	60	53	62	1.71	−2.5	3	4,641	s.	23	ne.	6	15	10	5	3.9	0.0	0.0
Corinth	469	6					67.5		91	24	79	38	1	56	37				1.09		8		s.				4	21	5		0.0	0.0
Meridian	375	85	93	29.61	30.00	−.02	69.0	+5.0	90	24	80	42	1	58	36	60	54	65	0.86	−4.2	3	4,086	s.	21	n.	3	14	14	2	4.3	0.0	0.0
Vicksburg	247	65	73	29.74	30.02	+.02	70.6	+5.0	89	23	80	47	30	61	28	60	54	63	2.49	−2.7	3	4,960	s.	24	nw.	29	8	13	9	5.2	0.0	0.0
New Orleans	53	76	84	29.96	30.01	+.01	72.4	+3.6	88	20	81	54	30	64	22	64	60	74	0.70	−4.2	4	4,672	s.	23	nw.	4	15	13	2	3.5	0.0	0.0
West Gulf States							**71.3**	**+5.0**										**70**	**1.67**	**−1.8**										**4.5**		
Shreveport	249	77	93	29.71	29.98	+.01	70.9	+5.1	91	21	81	46	30	61	26	60	55	63	0.76	−3.8	2	5,308	se.	24	s.	17	14	13	3	4.1	0.0	0.0
Bentonville	1,303	11	44	28.59	29.95	−.01	63.7	+6.8	86	21	74	36	30	53	31				4.94		12	2,554	s.	17	nw.	29	16	8	6		0.0	0.0
Fort Smith	457	79	94	29.45	29.93	−.03	67.6	+5.8	89	17	77	43	30	58	31	58	52	64	5.01	+1.1	10	6,879	e.	43	w.	24	6	14	10	5.6	0.0	0.0
Little Rock	357	136	144	29.58	29.96	−.02	68.2	+6.1	90	15	78	47	30	58	32	57	50	58	1.08	−3.4	6	7,829	s.	44	s.	13	12	9	9	4.7	0.0	0.0
Brownsville	57	53	61	29.85	29.91		75.0	+2.3	88	20	82	49	30	68	22	68	67	84	1.65		3	7,235	se.	29	s.	23	10	13	7	4.6	0.0	0.0
Corpus Christi	20	11	73	29.93	29.95	.00	74.0	+3.2	86	27	79	51	30	69	21	68	66	82	0 02	−1.8	1	12,415	se.	38	se.	23	10	14	6	4.7	0.0	0.0
Dallas	512	109	117	29.40	29.94		71.4		96	18	82	47	5	61	30				2.69		6	8,126	s.	38	s.	22	12	15	3	4.2	0.0	0.0
Fort Worth	670	106	114	29.19	29.89	−.05	72.3	+7.3	100	18	83	50	5	62	34	61	55	61	3.59	+0.9	5	9,283	s.	56	nw.	26	9	12	9	5.2	0.0	0.0
Galveston	54	106	114	29.94	30.00	+.03	72.2	+3.5	83	10	76	46	30	68	17	66	64	82	1.58	−1.6	3	9,504	s.	32	se.	23	19	9	2	3.0	0.0	0.0
Groesbeck	461	11	56	29.47	29.95		71.7		93	18	83	48	30	61	33				2.38		7	10,079	s.	52	nw.	26	11	13	6	4.8	0.0	0.0
Houston	138	111	121	29.84	29.98		73.0	+3.4	89	9	82	48	30	64	30				2.93		4	5,561	se.	37	ne.	28	13	12	5	3.9	0.0	0.0
Palestine	510	64	72	29.44	29.97	+.01	70.8	+4.8	90	19	81	49	4	61	28	60	55	64	1.05	−3.0	6	6,942	s.	32	s.	20	8	15	7	5.0	0.0	0.0
Port Arthur	34	58	66	29.95	29.99		71.8		84	15	79	49	30	65	23	65	63	80	2.06		4	8,072	se	37	e.	27	16	10	4	3.5	0.0	0.0
San Antonio	693	119	132	29.20	29.92	−.01	74.2	+5.1	95	18	84	47	30	64	32	63	57	63	0.18	−2.8	2	7,004	se.	31	ne.	29	11	10	9	5.2	0.0	0.0
Taylor	583	55	63	29.37	29.98	+.03	73.8	+6.3	96	18	85	46	30	63	35				1.76	−2.2	7	8,939	se.	34	s.	22	11	12	7	5.0	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1925*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dewpoint	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							**59.7**	**+4.9**										**63**	**2.20**	**−1.4**										**5.3**		
Chattanooga	762	189	213	29.19	30.00	−.03	64.8	+4.5	92	24	75	40	1	55	30	54	47	60	2.15	−2.2	10	5,414	w.	38	w.	10	12	8	10	5.2	0.0	0.0
Knoxville	996	102	111	28.95	30.00	−.03	63.4	+5.4	93	24	74	37	1	53	34	54	47	64	2.30	−2.3	10	4,585	ne.	36	sw.	25	11	6	13	5.5	0.0	0.0
Memphis	399	76	97	29.56	29.98	−.02	68.2	+6.4	88	24	77	44	30	60	26	57	50	57	0.89	−3.9	6	5,189	s.	38	nw.	29	12	9	9	4.8	0.0	0.0
Nashville	546	168	191	29.43	30.01	.00	64.2	+5.2	90	24	74	38	1	55	28	55	49	64	3.74	−0.6	11	6,560	ne.	37	w.	29	13	7	10	4.7	0.0	0.0
Lexington	989	193	230	28.95	30.02	.00	59.2	+4.9	90	24	69	33	1	49	33				2.49	−0.8	12	9,988	sw.	44	sw.	19	14	5	11	4.9	0.0	0.0
Louisville	525	188	234	29.43	30.01	.00	61.4	+5.0	91	24	72	35	6	51	33	52	45	61	2.21	−1.9	9	8,049	s.	38	w.	29	10	10	10	4.9	0.0	0.0
Evansville	431	139	175	29.53	30.00	.00	62.8	+6.1	89	24	73	36	1	52	31	53	45	58	1.55	−1.9	10	8,469	sw.	40	w.	29	10	15	5	5.0	0.0	0.0
Indianapolis	822	194	230	29.12	30.01	+.01	57.6	+5.5	90	24	68	28	5	47	37	49	43	63	1.98	−1.5	10	8,502	ne.	38	nw.	11	10	12	8	5.2	T.	0.0
Royal Center	736	11	55	29.22	30.02		53.6		86	24	66	25	5	41	39				2.11		9	8,121	e.	39	w.	13	9	8	13	6.0	T.	0.0
Terre Haute	575	96	129	29.37	29.99		59.2		89	24	70	31	1	48	35	51	44	65	1.70		10	7,140	n.	31	s.	24	6	17	7	5.4	0.0	0.0
Cincinnati	628	11	51	29.33	30.01	.00	58.2	+5.8	90	24	70	30	6	47	38		49	72	1.84	−1.1	13	5,721	ne.	30	sw.	19	12	10	8	4.6	0.0	0.0
Columbus	824	179	222	29.15	30.03	+.01	55.2	+4.0	87	24	66	29	1	44	38	48	42	65	1.68	−1.2	10	7,964	e.	62	w.	11	11	8	11	5.0	T.	0.0
Dayton	899	137	173	29.05	30.00		56.4	+4.8	88	24	68	30	5	45	38	48	41	61	3.57	+0.7	10	6,878	ne.	44	w.	9	12	10	8	4.8	0.0	0.0
Elkins	1,947	59	67	27.98	30.04	+.01	52.8	+4.0	90	24	65	25	7	40	44	45	39	70	3.32	0.0	17	3,722	nw.	36	nw.	19	6	9	15	6.6	1.0	T.
Parkersburg	638	77	84	29.38	30.04	+.01	57.0	+3.6	93	24	69	32	3	45	41	48	41	62	1.67	−1.2	8	3,817	se.	40	sw.	19	11	6	13	5.6	0.0	0.0
Pittsburgh	842	353	410	29.12	30.03	+.01	54.4	+3.2	90	24	66	30	5	43	36	46	39	61	1.43	−1.5	11	7,346	nw.	56	nw.	19	9	9	12	5.9	T.	0.0
Lower Lake Region							**48.4**	**+3.0**										**65**	**1.87**	**−0.5**										**4.8**		
Buffalo	767	247	280	29.20	30.04	+.03	44.7	+1.9	76	24	53	26	5	36	31	41	37	77	1.41	−1.0	6	10,111	sw.	56	sw.	15	10	14	6	5.2	0.3	0.0
Canton	448	10	61	29.53	30.01		42.2	−0.3	79	25	52	21	21	33	39				1.67	−0.6	6	8,072	w.	46	e.	30	15	6	9	4.3	11.1	0.0
Oswego	335	76	91		30.03	+.02	43.6	0.0	79	25	51	26	6	36	29			70	2.60	+0.3	9		w.	32	se.	14	12	8	10		4.5	0.0
Rochester	523	86	102	29.46	30.05	+.04	47.3	+2.4	82	25	56	27	6	39	36	40	32	58	2.04	−0.4	9	5,861	nw.	30	w.	26	13	9	8	5.0	1.0	0.0
Syracuse	597	97	113	29.41	30.06	+.05	46.2	+1.8	81	25	55	25	5	37	33				2.92	+0.6	10	7,986	nw.	50	s.	14	12	10	8	5.2	1.6	0.0
Erie	714	130	166	29.25	30.02	.00	48.9	+3.8	84	24	57	27	5	40	33	44	39	72	2.88	+0.5	9	9,497	ne.	42	s.	14	10	14	6	4.5	1.5	0.0
Cleveland	762	190	201	29.20	30.03	+.01	50.6	+4.4	88	24	60	30	5	42	37	43	36	63	1.37	−0.9	9	9,070	ne.	45	n.	19	8	12	10	5.4	0.0	0.0
Sandusky	629	62	70	29.36	30.05	+.03	51.5	+4.3	89	24	60	33	5	43	37				1.08	−1.5	9	6,381	ne.	30	nw.	26	9	11	10	5.5	0.0	0.0
Toledo	628	208	243	29.35	30.04	+.03	52.0	+4.4	88	24	62	28	5	42	38	44	37	61	1.31	−1.0	11	9,989	ne.	43	nw.	26	14	12	4	4.0	0.0	0.0
Fort Wayne	856	113	124	29.10	30.03		54.0	+4.7	88	24	65	27	5	43	40	46	38	62	2.21		9	6,461	e.	36	w.	13	12	9	9	4.5	0.0	0.0
Detroit	730	218	258	29.25	30.05	+.03	51.4	+5.2	88	23	62	28	5	41	40	42	34	59	1.42	−0.9	8	8,142	ne.	34	sw.	26	13	10	7	4.6	0.0	0.0
Upper Lake Region							**46.3**	**+4.5**										**65**	**1.65**	**−0.7**										**4.7**		
Alpena	609	13	92	29.40	30.07	+.05	42.4	+3.8	84	24	51	24	6	34	43	37	31	67	1.00	−1.2	7	9,214	se.	46	nw.	12	11	13	6	4.7	3.2	0.0
Escanaba	612	54	60	29.40	30.08	+.06	42.5	+4.6	76	25	51	20	5	34	28	36	30	65	0.51	−1.6	5	7,299	s.	34	ne.	30	14	11	5	3.8	T.	0.0
Grand Haven	632	54	89	29.34	30.02	+.01	47.8	+4.1	73	23	58	24	5	38	27	41	35	66	2.74	+0.3	11	8,069	e.	38	w.	24	12	10	8	4.9	0.0	0.0
Grand Rapids	707	70	87	29.27	30.05	+.03	51.8	+4.8	84	23	63	26	5	41	33	43	34	57	3.17	+0.7	11	4,785	e.	36	se.	19	12	10	8	4.9	0.0	0.0
Houghton	668	62	99	29.34	30.08	+.06	42.6	+4.9	81	24	52	19	5	34	41				0.35	−1.7	4	8,062	e.	48	e.	23	13	12	6	4.4	T.	0.0
Lansing	878	11	62	29.08	30.03		50.2	+4.6	86	23	63	23	6	37	42	43	37	70	1.86	−0.7	10	5,084	ne.	27	nw.	13	15	10	5	3.9	0.0	0.0
Ludington	637	60	66	29.34	30.04		45.8		72	23	56	21	5	36	29	40	34	69	3.05		10	7,735	n.	33	se.	18	14	12	4	3.8	T.	0.0
Marquette	734	77	111	29.28	30.10	+.08	43.0	+5.2	83	24	51	20	5	34	35	36	29	61	0.75	−1.2	4	6,791	nw.	44	s.	13	9	10	11	5.2	T.	0.0
Port Huron	638	70	120	29.34	30.04	+.02	47.1	+4.1	87	23	57	28	5	37	38	40	34	66	1.44	−0.6	9	9,002	ne.	44	nw.	12	15	13	2	3.4	0.0	0.0
Saginaw	641	69	77	29.35	30.05		48.0	+3.1	87	23	60	24	6	36	38	41	34	64	2.23	−0.5	8	7,068	ne.	34	ne.	29	8	13	9	5.4	T.	0.0
Sault Sainte Marie	614	11	52	29.38	30.09	+.06	41.4	+4.0	76	24	51	20	5	32	30	35	28	63	0.33	−1.7	5	6,587	se.	35	nw.	12	12	12	6	4.6	0.5	0.0
Chicago	823	140	310	29.13	30.02	+.02	52.6	+4.9	86	23	61	34	5	44	35	45	38	66	3.15	+0.3	9	8,442	n.	37	ne.	19	11	8	11	5.4	0.0	0.0
Green Bay	617	109	141	29.36	30.02	+.01	48.0	+4.8	82	23	59	23	5	37	37	40	33	61	1.84	−0.6	8	8,356	ne.	45	ne.	18	8	13	9	5.1	0.6	0.0
Milwaukee	681	125	139	29.28	30.03	+.04	49.2	+5.4	84	23	57	33	5	41	33	43	37	68	2.69	0.0	10	8,200	ne.	62	se.	19	11	9	10	5.5	0.0	0.0
Duluth	1,133	5	47	28.81	30.05	+.04	42.0	+5.0	72	9	51	24	5	33	38	35	27	62	1.03	−1.1	6	10,229	ne.	45	sw.	24	10	13	7	5.0	4.4	0.0
North Dakota							**48.7**	**+8.0**										**63**	**1.52**	**−0.3**										**5.2**		
Moorhead	940	50	58	28.95	29.98	−.01	49.6	+9.0	84	10	61	27	16	38	41	43	36	65	1.99	−0.3	9	5,230	se.	25	se.	25	16	7	7	4.4	0.0	0.0
Bismarck	1,674	8	57	28.20	29.99	+.02	51.0	+8.9	83	10	64	24	30	38	47	41	32	58	0.86	−1.0	10	8,588	e.	44	s.	20	14	11	5	4.0	T.	0.0
Devils Lake	1,478	11	44	28.39	29.98	+.01	46.6	+8.4	79	10	58	23	16	35	36	39	32	64	1.79	−0.2	6	8,468	ne.	35	n.	28	10	13	7	5.2	0.2	0.0
Ellendale	1,457	10	56	28.42	29.99		49.3		81	10	62	25	16	36	45				2.27		7	11,003	nw.	50	nw.	12	6	8	16	6.9	T.	0.0
Grand Forks	835	12	89				48.0		82	10	60	24	16	36	45	41			1.58		8		nw.	39	se.	5	19	7	4	4.5	0.0	0.0
Williston	1,878	41	48	27.96	29.95	−.01	47.6	+5.6	76	11	58	27	29	37	39	40	34	65	1.45	+0.2	12	7,947	se.	42	w.	25	11	7	12	5.3	0.4	0.0
Upper Mississippi Valley							**57.0**	**+6.8**										**61**	**2.09**	**−0.9**										**5.4**		
Minneapolis	918	102	208	28.98	29.97		53.2	+5.8	85	22	63	31	5	43	34				1.21	−1.2	10	8,617	se.	36	sw.	23	7	13	10	5.9	0.0	0.0
St. Paul	837	236	261	29.09	30.00	+.01	52.6	+7.0	83	22	62	30	5	43	33				1.27	−1.1	9	9,255	se.	45	sw.	23	8	16	6	5.2	0.0	0.0
La Crosse	714	11	48	29.24	30.01	+.03	53.6	+6.4	89	22	66	29	1	42	40				1.39	−0.9	7	3,791	e.	28	w.	22	11	9	10	5.3	0.0	0.0
Madison	974	70	78	28.98	30.03	+.04	51.5	+6.1	82	23	62	26	5	41	34	43	35	59	1.69	−0.7	11	6,969	se.	36	ne.	29	9	8	13	5.8	0.0	0.0
Wausau	1,247	4		28.70	30.06		48.4		83	23	61	21	5	36	42				1.84		7		s.				10	7	13	5.5	3.4	0.0
Charles City	1,015	10	49	28.91	30.00	+.02	54.0	+7.6	90	22	67	29	5	41	37	45	37	60	1.15	−1.7	11	5,111	se.	31	se.	23	14	9	7	4.2	T.	0.0
Davenport	606	71	79	29.33	29.99	+.01	56.6	+6.7	87	22	68	29	5	45	38	49	44	67	4.48	+1.6	11	5,536	e.	30	e.	20	12	9	9	5.0	0.7	0.0
Des Moines	861	84	97	29.06	29.97	.00	58.2	+8.1	88	22	69	33	5	47	36	48	40	59	1.64	−1.3	6	6,089	se.	40	sw.	26	7	9	14	6.2	T.	0.0
Dubuque	700	81	96	29.23	29.98	.00	54.8	+6.2	88	22	66	27	5	43	34	45	36	57	2.17	−0.8	9	4,748	se.	33	n.	14	9	7	14	6.2	0.0	0.0
Keokuk	614	64	78	29.31	29.98	.00	59.1	+6.8	88	22	70	29	5	48	34	51	44	63	3.67	+0.3	9	5,693	e.	32	n.	29	8	14	8	5.5	0.0	0.0
Cairo	358	87	93	29.59	29.97	−.02	65.0	+6.9	88	24	75	41	1	55	32	55	48	60	1.66	−1.9	6	7,309	s.	35	ne.	27	8	14	8	5.5	0.0	0.0
Peoria	609	11	45	29.34	30.00	+.01	57.8	+6.9	87	22	70	28	1	46	40	49	42	64	1.68	−1.6	11	5,395	ne.	39	w.	19	8	14	8	5.1	0.0	0.0
Springfield, Ill	636	10	91	29.29	29.96	−.02	59.4	+6.7	89	24	71	30	5	48	34	50	44	63	2.59	−0.7	10	6,350	s.	37	nw.	13	11	10	9	5.0	0.0	0.0
Hannibal	534	74	109	29.42	29.99	+.01	60.2	+6.8	89	22	70	32	5	50	32				1.90	−1.4	10	6,830	e.	32	sw.	24	10	9	11	5.5	0.0	0.0
St. Louis	568	265	303	29.37	29.97	−.01	62.6	+6.8	91	22	72	36	5	53	31	53	45	61	2.70	−0.8	13	9,975	sw.	50	nw.	29	12	9	9	5.0	0.0	0.0
Missouri Valley							**58.5**	**+7.6**										**61**	**2.84**	**0.0**										**5.3**		
Columbia, Mo	784	11	84	29.14	29.98	.00	60.8	+5.9	89	22	71	34	5	51	34				4.38	+0.7	14	6,476	e.	37	w.	19	10	9	11	5.3	0.0	0.0
Kansas City	963	161	181	28.93	29.96	.00	60.2	+5.4	85	22	68	38	30	52	29	54	49	71	5.16	+1.9	13	8,320	e.	56	nw.	29	11	8	11	5.2	0.0	0.0
St. Joseph	967	11	49	28.92	29.95		59.7		87	22	69	38	30	51	30	52	46	66	3.96		16	7,144	se.	43	nw.	29	10	10	10	4.9	0.0	0.0
Springfield, Mo	1,324	98	104	28.57	29.96	−.01	62.0	+6.0	86	22	71	36	30	53	25	53	46	62	2.68	−1.2	11	9,074	se.	43	nw.	29	16	9	5	3.7	0.0	0.0
Iola	984	11	50	28.89	29.92	−.03	61.9	+7.7	84	20	72	37	30	52	34				6.31	+3.5	12	5,894	s.	32	nw.	29	8	10	12	5.7	0.0	0.0
Topeka	987	92	107				60.3	+5.6	86	22	70	36	30	51	34				4.40	+1.7	12	8,452	e.	51	nw.	29	10	8	12	5.4	0.0	0.0
Drexel	1,299	10	54	28.56	29.95		57.4		87	22	68	32	30	47	32				1.90		9	8,692	se.	48	se.	20	8	9	13	5.7	0.0	0.0
Lincoln	1,189	11	84	28.69	29.94	.00	59.4	+7.9	88	22	70	33	30	49	36	50	42	59	1.55	−1.2	8	8,289	se.	44	nw.	29	8	10	12	6.1	0.0	0.0
Omaha	1,105	115	122	28.78	29.96	+.01	60.0	+8.8	89	22	70	36	30	50	33	49	40	54	1.50	−1.5	8	6,228	se.	48	n.	29	9	12	9	5.2	0.0	0.0
Valentine	2,598	47	54	27.23	29.94	.00	53.6	+7.9	84	22	66	27	30	41	37	44	35	59	1.52	−0.8	9	7,913	w.	53	se.	22	9	12	9	5.2	0.0	0.0
Sioux City	1,135	94	164	28.76	29.97	+.02	57.7	+9.9	85	22	68	33	30	48	33	48	39	56	1.99	−0.8	6	10,029	se.	56	nw.	29	10	10	10	5.3	0.0	0.0
Huron	1,306	59	74	28.58	29.99	+.03	54.1	+9.0	85	12	66	28	30	42	39	45	37	61	1.71	−0.9	11	7,563	se.	38	se.	17	9	10	11	5.4	T.	0.0
Pierre	1,572	70	75	28.30	29.96	+.01	55.1	+8.3	82	12	67	30	30	44	36	45	36	57	0.95	−1.0	6	7,632	nw.	44	nw.	28	10	6	14	5.8	0.0	0.0
Yankton	1,233	49	57	28.64	29.96	+.01	56.8	+8.9	84	12	68	30	30	46	39				1.96	−0.8	9	6,332	nw.	38	s.	22	9	9	12	5.8	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1925*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation: Thermometer above ground	Elevation: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dewpoint	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							47.6	+4.4										59	1.62	0.0										5.3		
Billings	3,140	5																														
Havre	2,505	11	44	27.29	29.94	+.01	47.1	+3.4	78	9	59	28	28	35	40	41	35	69	2.66	+1.6	11	5,506	e.	37	w.	12	11	11	8	5.1	0.2	0.0
Helena	4,110	87	112	25.74	29.94	−.03	46.2	+2.7	74	30	56	29	28	36	38	38	29	57	2.86	+1.7	8	5,996	sw.	42	sw.	23	8	9	13	6.1	3.3	0.0
Kalispell	2,973	48	56	26.86	29.91	−.05	47.0	+3.4	74	30	58	28	28	35	38	39	29	56	0.87	−0.2	8	4,622	nw.	26	sw.	12	9	15	6	5.1	T.	0.0
Miles City	2,371	48	55	27.42	29.98	+.02	51.1	+6.4	79	11	62	27	29	41	33	43	35	61	0.74	−0.4	12	5,440	se.	30	se.	4	11	7	12	4.9	0.0	0.0
Rapid City	3,259	50	58	26.56	29.97	+.02	50.7	+6.4	76	11	62	26	30	40	32	42	33	57	1.89	−0.4	6	5,931	w.	36	nw.	28	10	11	9	5.3	T.	0.0
Cheyenne	6,088	84	101	23.94	29.90	−.01	45.2	+4.3	74	17	57	18	29	33	35	36	27	55	1.23	−0.6	4	10,792	w.	62	s.	22	8	11	11	5.7	1.4	0.0
Lander	5,372	60	68	24.58	29.94	.00	46.0	+3.6	70	16	58	23	29	34	38	37	26	52	0.57	−1.9	8	5,008	w.	40	nw.	17	14	8	8	4.8	0.2	0.0
Sheridan	3,790	10	47	26.04	29.94	-----	48.2	-----	76	11	60	21	29	36	42	40	31	59	5.52	-----	11	5,445	nw.	32	se.	4	10	11	9	5.3	0.3	0.0
Yellowstone Park	6,241	11	48	23.82	29.95	−.01	40.2	+3.2	64	11	51	21	28	29	38	33	26	62	1.95	+0.6	13	5,867	s.	41	sw.	17	5	15	10	5.9	5.9	0.0
North Platte	2,821	11	51	27.04	29.96	+.04	54.6	+6.0	89	21	68	26	30	42	39	45	36	61	1.78	−0.4	9	6,093	se.	39	sw.	22	13	7	10	4.7	T.	0.0
Middle Slope							**59.2**	**+5.8**										**54**	**2.27**	**0.0**										**4.8**		
Denver	5,292	106	113	24.66	29.88	−.02	52.8	+5.7	81	17	65	30	29	41	33	40	25	41	0.40	−1.8	5	6,562	s.	46	se.	5	11	17	2	4.2	T.	0.0
Pueblo	4,685	80	86	25.22	29.87	−.01	54.4	+4.3	85	17	70	28	7	39	42	40	25	39	0.06	−1.4	2	6,446	nw.	54	nw.	1	14	14	2	4.0	0.0	0.0
Concordia	1,392	50	58	28.46	29.92	−.01	60.2	+6.7	87	21	70	33	30	50	36	50	42	58	1.24	−1.2	11	6,968	se.	36	nw.	28	10	10	10	5.3	0.0	0.0
Dodge City	2,509	11	51	27.35	29.93	−.03	59.6	+6.0	90	21	73	32	29	46	38	48	40	60	3.33	+1.5	6	8,036	se.	44	se.	6	16	7	7	3.9	0.0	0.0
Wichita	1,358	139	158	28.48	29.90	−.03	62.2	+5.8	89	20	72	36	29	52	30	53	47	63	4.55	+1.9	11	10,947	s.	48	sw.	22	10	13	7	5.1	0.0	0.0
Broken Arrow	765	11	56	29.12	29.94	-----	64.4	-----	91	18	74	40	30	55	29	-----	-----	-----	4.04	-----	15	11,009	se.	40	se.	2	8	13	9	5.8	0.0	0.0
Muskogee	652	4	-----	-----	-----	-----	66.8	-----	90	18	78	38	30	56	35	-----	-----	-----	5.61	-----	13	-----	se.	-----	-----	-----	8	13	9	-----	0.0	0.0
Oklahoma City	1,214	10	47	28.65	29.91	−.01	66.3	+6.5	96	18	77	40	29	56	31	56	49	63	4.02	+1.2	10	8,167	s.	33	s.	22	7	18	5	5.0	0.0	0.0
Southern Slope							**67.9**	**+5.1**										**44**	**1.94**	**+0.2**										**4.0**		
Abilene	1,738	10	52	28.11	29.89	−.01	70.7	+6.3	102	18	82	43	5	59	36	57	47	55	5.03	+2.8	9	8,703	s.	47	s.	12	11	8	11	5.0	0.0	0.0
Amarillo	3,676	10	49	26.20	29.88	+.01	61.1	+5.3	89	21	75	36	4	47	41	47	34	48	1.33	−0.4	3	7,878	se.	37	sw.	23	13	10	7	4.4	0.0	0.0
Del Rio	944	64	71	28.92	29.88	−.01	76.0	+5.4	100	17	86	47	30	66	34	-----	-----	-----	1.42	−0.5	4	8,587	se.	64	nw.	26	17	4	9	4.5	0.0	0.0
Roswell	3,566	75	85	26.29	29.84	−.01	63.9	+3.3	95	16	79	36	4	49	45	45	21	28	T.	−0.9	0	6,956	s.	39	sw.	22	23	6	1	2.2	0.0	0.0
Southern Plateau							**60.3**	**+3.0**										**36**	**0.29**	**−0.1**										**2.4**		
El Paso	3,762	110	133	26.11	29.81	−.02	67.6	+4.2	93	15	81	42	30	54	37	47	23	23	T.	−0.2	0	8,290	nw.	46	e.	29	22	6	2	2.3	0.0	0.0
Santa Fe	7,013	38	53	23.20	29.83	−.01	50.6	+3.9	76	16	64	28	24	38	35	37	19	34	0.24	−0.6	2	6,011	sw.	35	sw.	1	15	11	4	3.6	T.	0.0
Flagstaff	6,907	10	59	23.31	29.87	+.03	44.0	+1.8	72	12	59	11	24	28	42	34	-----	54	2.01	-----	5	6,636	sw.	36	sw.	19	16	8	6	-----	6.5	0.0
Phoenix	1,108	10	82	28.71	29.86	−.01	70.8	+3.8	103	14	87	44	2	55	43	52	34	32	0.51	+0.1	2	3,927	w.	50	w.	21	22	6	2	2.3	0.0	0.0
Yuma	141	9	54	29.72	29.87	−.02	70.4	+0.9	104	14	87	43	22	54	46	54	39	39	0.34	+0.2	2	3,910	w.	28	nw.	21	25	4	1	1.6	0.0	0.0
Independence	3,957	5	25	25.94	29.96	+.06	58.2	+3.1	85	14	73	28	22	43	41	42	-----	-----	0.34	+0.2	3	-----	nw.	-----	-----	-----	11	15	4	-----	T.	0.0
Middle Plateau							**50.6**	**+2.2**										**49**	**1.09**	**+0.1**										**4.7**		
Reno	4,532	74	81	25.41	29.93	−.04	49.6	+2.3	76	14	62	26	1	37	38	40	30	54	0.50	+0.1	8	5,730	w.	45	w.	17	11	10	9	4.6	0.9	0.0
Tonopah	6,090	12	20	-----	-----	-----	48.3	-----	71	15	57	20	1	39	28	38	27	50	1.00	-----	7	-----	nw.	-----	-----	-----	-----	-----	-----	-----	0.0	0.0
Winnemucca	4,344	18	56	25.56	29.94	−.02	49.2	+2.5	75	14	63	27	2	36	41	40	30	55	1.33	+0.4	10	5,594	sw.	31	w.	17	11	9	10	5.1	0.2	0.0
Modena	5,479	10	43	24.55	29.89	+.01	46.7	+0.7	77	15	62	24	2	32	43	36	25	51	1.74	+1.0	9	7,679	w.	62	sw.	20	15	8	7	4.2	10.7	0.0
Salt Lake City	4,360	163	203	25.55	29.90	−.02	51.7	+2.1	77	11	61	34	22	42	29	41	30	49	1.42	−0.8	8	5,135	nw.	42	sw.	17	15	5	10	4.9	T.	0.0
Grand Junction	4,602	60	68	25.30	29.86	−.02	55.6	+3.2	83	16	69	34	1	42	35	41	24	36	0.47	−0.3	5	5,305	se.	39	s.	22	13	9	8	4.8	T.	0.0
Northern Plateau							**52.3**	**+3.0**										**57**	**1.31**	**−0.1**										**5.6**		
Baker	3,471	48	53	26.40	29.99	−.01	47.4	+2.2	74	10	59	28	28	36	36	40	33	63	1.36	+0.4	9	4,557	se.	32	s.	15	7	11	12	5.9	T.	0.0
Boise	2,739	78	86	27.11	29.97	−.01	52.7	+2.3	79	10	64	31	25	41	35	44	35	56	0.87	−0.3	9	3,976	se.	37	se.	3	14	3	13	5.1	0.0	0.0
Lewiston	757	40	48	29.16	29.97	−.02	56.1	+3.2	85	29	69	34	28	43	43	-----	-----	-----	1.27	+0.1	9	2,562	e.	29	nw.	15	10	6	14	6.1	0.0	0.0
Pocatello	4,477	60	68	25.41	29.93	−.01	48.4	+2.4	75	30	59	29	28	37	37	39	30	55	2.09	+0.1	12	6,249	sw.	36	sw.	23	8	10	12	6.0	5.1	0.0
Spokane	1,929	101	110	27.91	29.96	−.03	51.9	+3.5	80	29	64	32	25	40	37	43	34	58	1.24	0.0	6	4,474	s.	30	sw.	23	8	10	12	5.8	T.	0.0
Walla Walla	991	57	65	28.89	29.96	−.05	57.2	+4.1	86	9	68	38	25	46	40	47	36	51	1.01	−0.7	9	3,827	s.	33	w.	15	11	12	7	5.0	T.	0.0
North Pacific Coast Region							**50.9**	**+1.8**										**74**	**3.08**	**−0.1**										**6.9**		
North Head	211	11	56	29.81	30.04	−.01	48.6	+1.1	77	28	53	40	20	44	27	46	43	84	4.07	+0.8	17	11,576	s.	56	s.	18	3	3	24	8.3	0.0	0.0
Port Angeles	29	8	53	-----	30.04	-----	47.4	-----	67	28	54	36	14	41	25	-----	-----	-----	1.53	−0.4	15	4,585	sw.	32	w.	23	6	6	12	-----	0.0	0.0
Seattle	125	215	250	29.92	30.05	+.02	50.6	+1.2	76	28	58	39	24	44	26	46	41	75	2.39	0.0	15	5,736	s.	43	sw.	16	4	13	13	6.9	0.0	0.0
Tacoma	213	113	120	29.83	30.04	+.01	50.6	+1.9	77	28	58	39	21	43	34	-----	-----	-----	2.99	+0.1	14	4,282	n.	22	n.	26	3	8	19	7.5	0.0	0.0
Tatoosh Island	86	7	57	29.92	30.02	+.02	47.6	+1.5	64	27	52	40	18	43	21	44	42	82	4.13	−2.2	19	9,440	w.	59	s.	30	8	5	17	6.7	0.0	0.0
Yakima	1,071	4	-----	-----	-----	-----	54.4	-----	85	9	69	29	28	39	45	-----	-----	-----	0.64	-----	5	-----	nw.	-----	-----	-----	11	11	8	5.3	0.0	0.0
Medford	1,425	4	-----	-----	-----	-----	53.6	-----	86	28	66	29	1	41	47	45	38	64	1.88	-----	13	-----	se.	24	se.	2	6	3	21	-----	0.0	0.0
Portland, Oreg.	153	68	106	29.85	30.01	−.05	54.2	+2.4	79	28	62	38	25	46	33	48	42	68	1.92	−1.1	14	4,266	nw.	28	w.	16	5	5	20	7.3	0.0	0.0
Roseburg	510	9	57	29.48	30.04	−.03	53.6	+2.6	88	28	64	34	1	43	44	48	41	72	4.52	+2.0	14	2,349	n.	20	sw.	19	5	13	12	6.0	0.0	0.0
Middle Pacific Coast Region							**55.6**	**+0.8**										**76**	**3.02**	**+0.8**										**5.3**		
Eureka	62	73	89	30.00	30.07	−.04	50.9	+1.0	70	15	56	38	20	46	21	48	46	84	7.47	+3.5	15	6,340	n.	39	n.	4	3	14	13	6.7	0.0	0.0
Point Reyes	490	7	18	29.46	29.98	-----	51.4	+0.8	70	14	56	44	1	47	20	-----	-----	-----	1.35	-----	11	13,190	nw.	70	nw.	21	7	8	15	6.2	0.0	0.0
Red Bluff	332	50	56	29.62	29.98	−.05	59.4	+0.4	92	28	70	39	1	48	39	52	47	69	1.74	−0.1	12	4,178	s.	28	s.	16	13	13	4	3.8	0.0	0.0
Sacramento	69	106	117	29.93	30.00	−.01	58.0	−0.1	82	27	67	36	21	49	31	53	50	76	1.61	−0.4	8	5,058	s.	28	nw	20	13	15	2	3.8	T.	0.0
San Francisco	155	208	243	29.85	30.02	−.03	57.0	+2.0	77	14	63	47	21	51	22	51	47	75	2.73	+0.9	8	6,137	w.	40	nw.	20	12	6	12	5.4	0.0	0.0
San Jose	141	12	110	29.88	30.04	-----	57.2	+0.5	83	15	67	38	21	47	36	-----	-----	-----	1.55	+0.1	7	4,390	nw.	28	nw.	20	10	6	14	5.7	0.0	0.0
South Pacific Coast Region							**59.0**	**+0.5**										**71**	**1.78**	**+0.8**										**4.8**		
Fresno	327	89	98	29.64	29.99	.00	60.6	+0.4	88	15	72	38	21	49	31	52	45	60	1.43	+0.7	3	4,868	nw.	27	nw.	9	14	8	8	4.4	0.0	0.0
Los Angeles	338	159	191	29.62	29.99	.00	60.0	+0.6	88	14	68	44	21	52	36	53	48	71	1.90	+0.8	5	3,916	sw.	23	sw.	20	13	11	6	4.5	0.0	0.0
San Diego	87	62	70	29.91	30.00	+.01	58.6	+0.1	81	16	65	46	21	52	24	53	51	79	1.11	+0.4	7	5,065	nw.	32	s.	21	9	9	12	5.6	0.0	0.0
San Luis Obispo	201	32	40	29.83	30.05	.00	56.6	+0.8	85	15	67	33	21	46	35	50	46	75	2.68	+1.2	9	3,119	nw.	19	nw.	17	10	11	9	4.9	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.86	29.94	-----	77.0	+0.4	89	3	83	69	22	71	18	-----	-----	-----	8.93	+5.1	17	6,969	s.	37	ne.	23	2	10	18	7.0	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.72	29.84	−.01	81.0	−0.5	92	21	89	68	7	73	24	75	74	85	2.63	−0.2	9	6,537	nw.	30	nw.	9	0	17	13	6.7	0.0	0.0
Colon	36	7	97	29.82	29.86	−.01	81.6	+0.6	89	20	86	73	17	77	14	76	74	83	5.47	+1.1	15	9,026	n.	28	nw.	17	1	17	12	6.9	0.0	0.0
Alaska																																
Juneau	80	11	54	-----	-----	-----	38.8	-----	54	21	45	24	1	32	22	36	32	81	6.25	-----	23	5,061	s.	26	se.	17	2	6	22	8.5	2.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, April, 1925*

Station	Altitude above mean sea level, Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
St. Johns, N. F	125												
Sydney, C. B. I	48	29.89	29.94	+0.05	36.1	+1.1	42.8	29.4	60	20	2.39	−1.46	3.5
Halifax, N. S	88	29.84	29.95	−.01	39.3	+1.5	47.3	31.3	59	22	3.81	−0.37	8.7
Yarmouth, N. S	65	29.85	29.92	−.04	39.2	+0.3	45.9	32.6	62	25	2.92	−0.47	15.4
Charlottetown, P. E. I	38	29.90	29.94	−.04	36.1	+0.9	42.8	29.4	55	22	0.46	−2.26	T.
Chatham, N. B	28	29.86	29.89	−.01	36.1	+0.6	45.1	27.1	67	14	2.38	−0.25	6.2
Father Point, Que	20	29.95	29.97	+.04	32.2	−1.0	36.9	27.5	51	14	2.63	+1.05	1.0
Quebec, Que	296	29.69	30.02	+.03	38.0	+2.9	45.4	30.7	69	16	1.92	−0.17	4.2
Montreal, Que	187	29.80	30.01	+.01	42.5	+2.8	51.1	33.8	79	20	2.55	+0.31	7.6
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.77	30.04	+.02	43.7	+3.7	54.3	33.1	78	21	1.01	−0.49	5.1
Kingston, Ont	285	29.71	30.03	+.01	43.0	+3.0	50.7	35.3	64	23	1.78	−0.01	7.6
Toronto, Ont	379	29.63	30.04	+.02	45.2	+4.4	54.2	36.1	79	25	1.31	−1.06	1.6
Cochrane, Ont	930				32.9		43.6	22.3	64	8	0.62		
White River, Ont	1,244	28.72	30.05	+.01	36.3	+3.3	48.6	24.0	67	4	1.17	−0.08	
Port Stanley, Ont	592												
Southampton, Ont	656	29.32			41.8	+3.1	51.2	32.3	80	20	3.29	+1.49	0.5
Parry Sound, Ont	688	29.33	30.03	+.01	41.8	+4.2	52.2	31.4	75	17	1.53	−0.38	2.7
Port Arthur, Ont	644	29.35	30.06	+.03	39.6	+6.1	48.1	31.1	69	19	1.62	−0.10	
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.16	30.00	−.01	41.7	+5.7	51.7	31.7	74	18	1.47	+0.41	T.
Le Pas, Man	860				37.5		48.8	26.2	67	12	0.80		2.5
Qu'Appelle, Sask	2,115	27.69	29.95	−.04	43.3	+5.9	53.9	32.7	71	24	1.51	+0.46	6.7
Medicine Hat, Alb	2,144	27.59	29.86	−.06	47.8	+3.3	58.6	37.0	80	26	2.66	+1.92	4.4
Moose Jaw, Sask	1,759				44.6		56.5	32.8	77	23	0.76		
Swift Current, Sask	2,392	27.39	29.93	−.03	44.9	+3.6	56.2	33.6	78	25	2.38	+1.45	1.0
Calgary, Alb	3,428												
Banff, Alb	4,521	25.32	29.90	.00	40.6	+5.3	53.9	27.4	67	17	0.76	−0.32	5.6
Edmonton, Alb	2,150	27.60	29.90	+.01	41.7	+1.8	52.2	31.2	71	20	2.56	+1.68	0.4
Prince Albert, Sask	1,450	28.43	30.02	+.04	41.9	+5.8	54.1	29.8	71	20	0.87	+0.04	4.4
Battleford, Sask	1,592	28.22	29.97	.00	42.1	+4.9	53.8	30.4	74	23	1.19	+0.72	
Kamloops, B. C	1,262	28.67	29.97	+.04	50.1	+1.2	61.8	38.4	78	30	0.59	+0.20	
Victoria, B. C	230	29.76	30.02	+.01	49.0	+2.2	55.1	42.9	71	39	1.70	−0.67	
Barkerville, B. C	4,180	25.59	29.92	+.06	35.3	+2.2	45.2	25.5	52	10	1.74	−0.08	12.3
Triangle Island, B. C	680												
Prince Rupert, B. C	170												
Hamilton, Ber	151	29.91	30.07	+.02	66.0	+2.1	72.1	60.0	77	53	2.89	−1.29	0.0

LATE REPORTS, MARCH, 1925

Station	Altitude	Station pressure	Sea level pressure	Departure	Mean	Departure	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure	Total snowfall
St. Johns, N. F	125	29.91	30.05	+.17	31.3	+3.6	36.4	26.2	50	10	5.36	+0.60	1.0
Charlottetown, P. E. I	38	30.05	30.09	+.19	31.6	+6.2	39.2	24.1	49	10	1.74	−1.47	8.2
Sydney, C. B. I	48	30.08	30.13	+.25	32.0	+5.8	39.8	24.1	51	6	3.67	−1.26	7.5
Halifax, N. S	88	30.00	30.11	+.17	35.1	+6.1	42.9	27.3	57	10	4.66	−0.80	3.2
Yarmouth, N. S	65	29.96	30.03	+.08	36.3	+5.5	43.1	29.5	62	16	3.27	−1.58	1.4
Chatham, N. B	28	29.97	30.00	+.10	28.2	+5.2	37.3	19.1	51	−13	3.98	+0.51	15.2
Port Arthur, Ont	644	29.32	30.05	.00	21.6	+4.8	30.5	12.8	59	−16	1.11	+0.14	11.0
Kamloops, B. C	1,262	28.69	30.00	+.08	40.9	+4.8	49.3	32.6	60	24	0.39	−0.18	2.7
Barkerville, B. C	4,180	25.53	29.90	+.02	25.2	−0.9	32.4	18.1	42	1	6.43	+4.54	61.0

Chart I. Tracks of Centers of Anticyclones, April, 1925. (Inset) Departure of Monthly Mean Pressure from Normal
(Plotted by Wilfred P. Day)

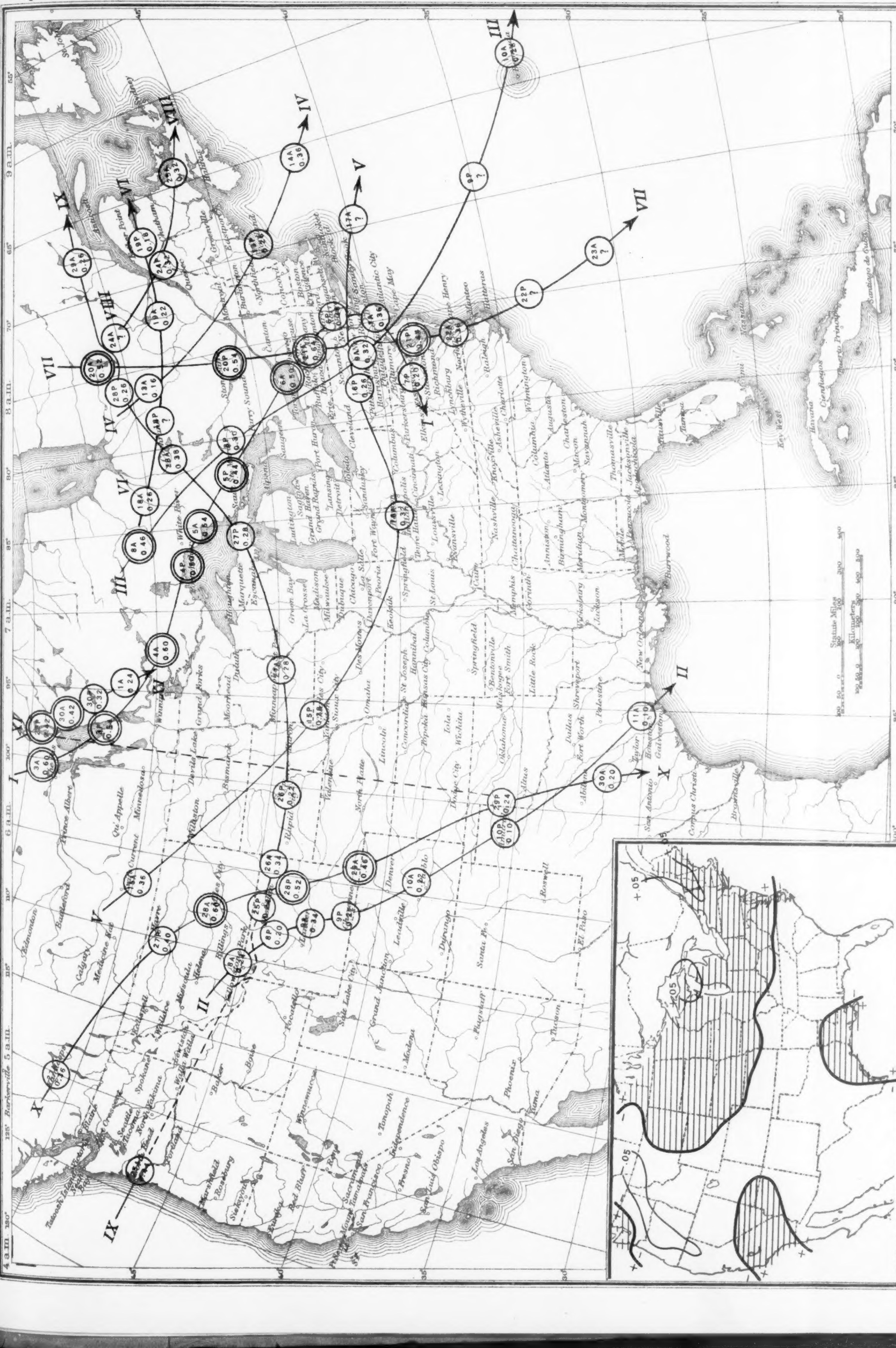

Chart II. Tracks of Centers of Cyclones, April, 1925. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

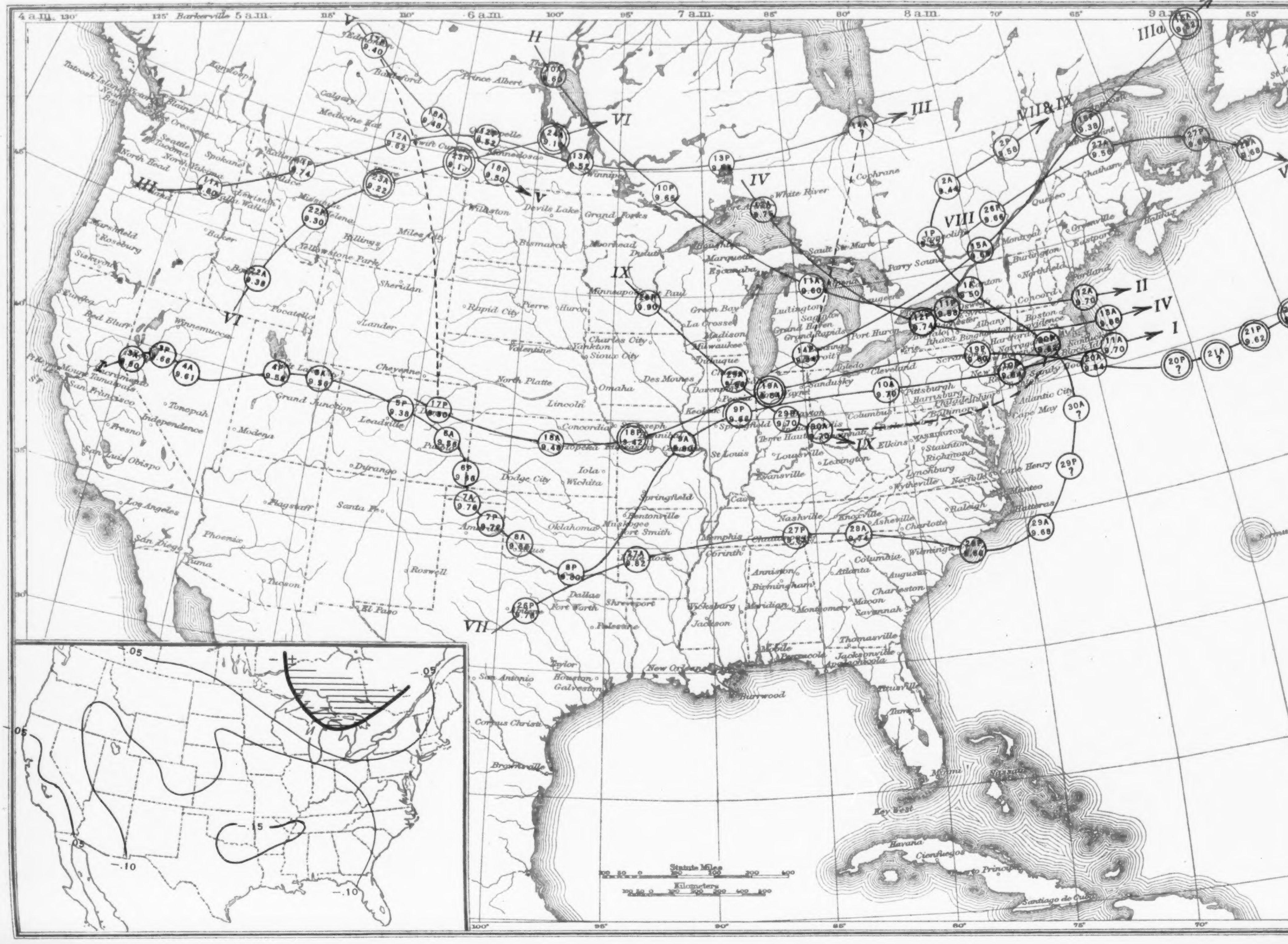

Chart III. Departure (°F.) of the Mean Temperature from the Normal, April, 1925

Chart IV. Total Precipitation, Inches, April, 1925. (Inset) Departure of Precipitation from Normal

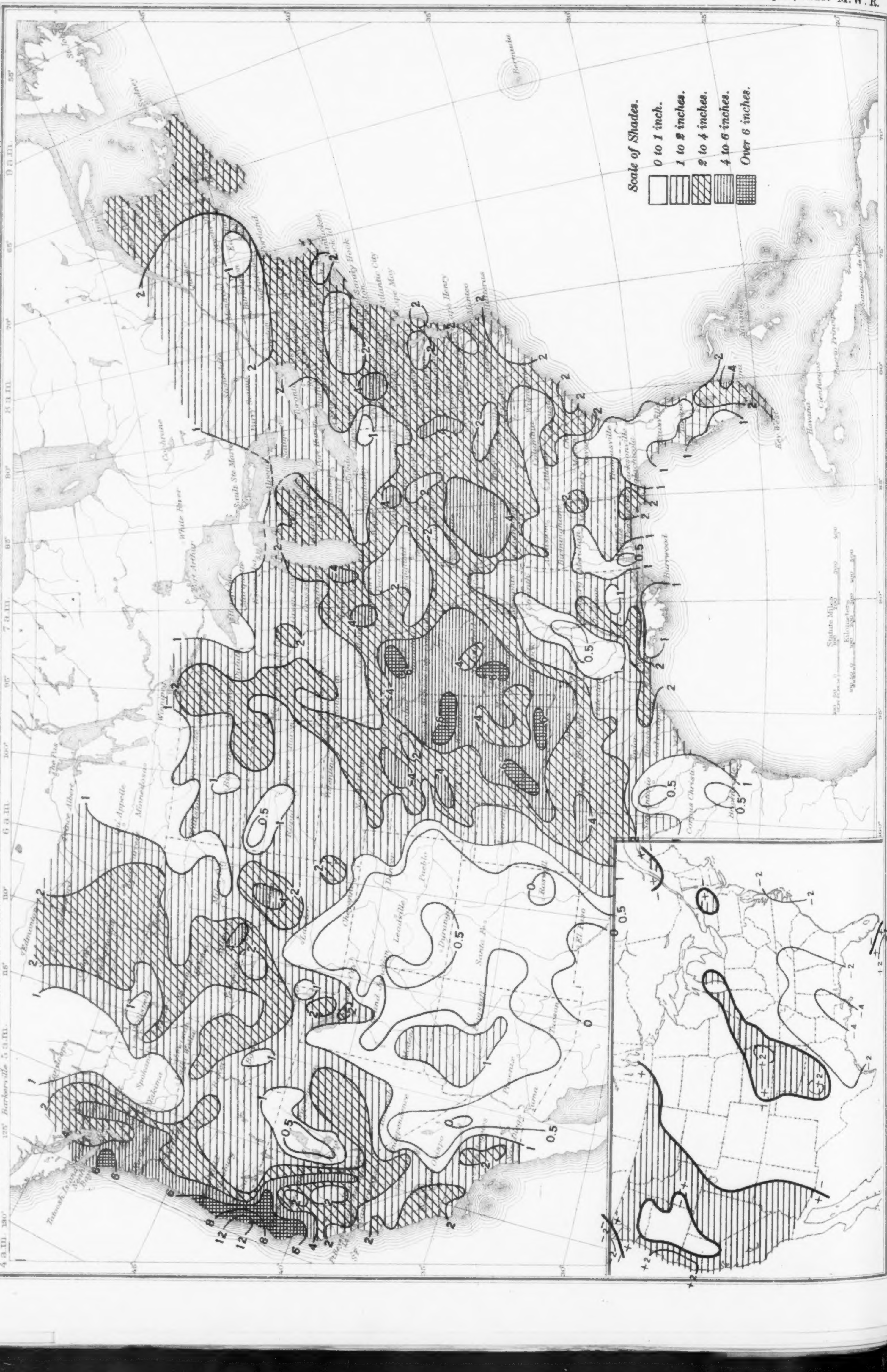

Chart V. Percentage of Clear Sky between Sunrise and Sunset, April, 1925

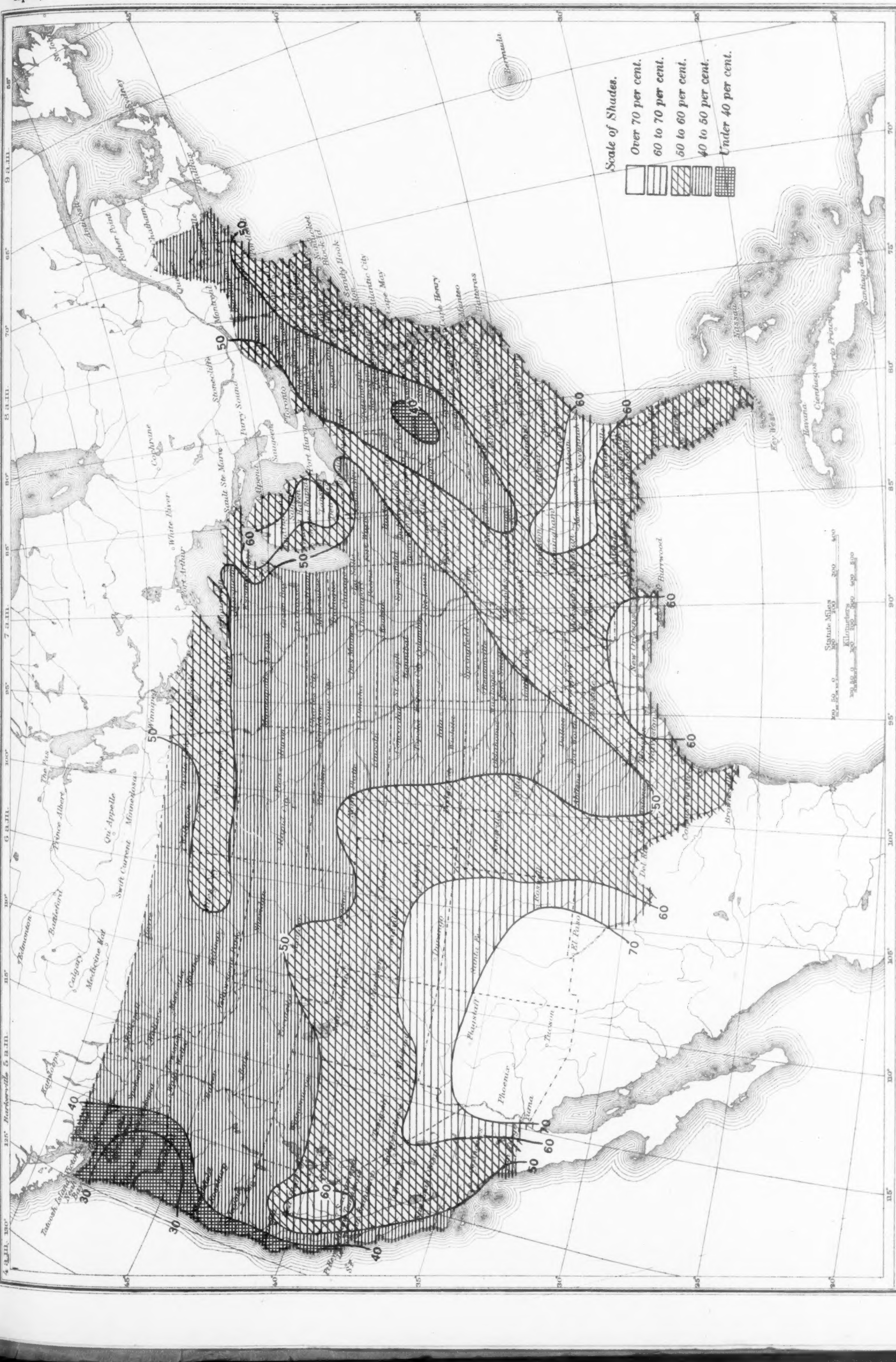

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, April, 1925

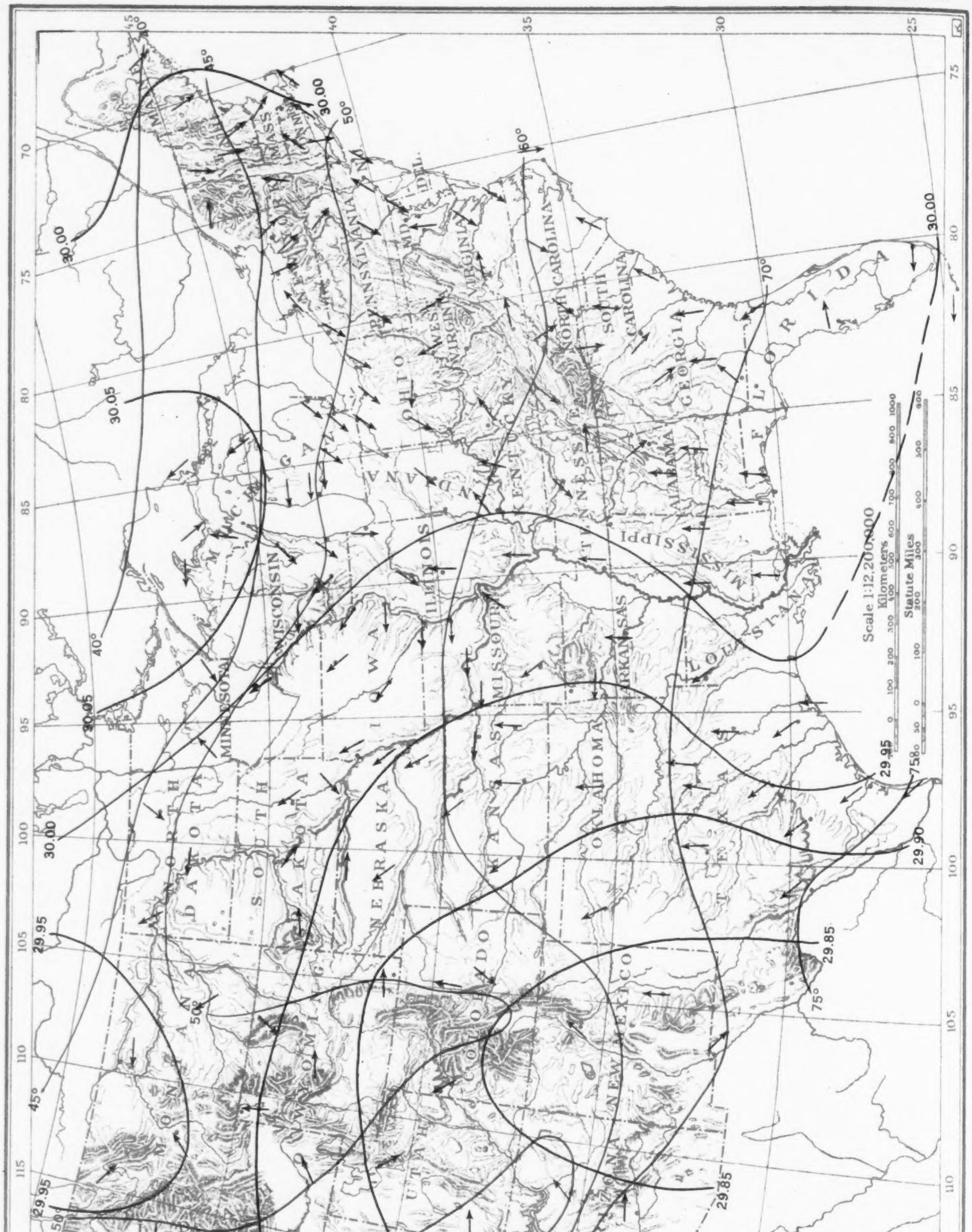

Chart VII. Total Snowfall, Inches, April, 1925.

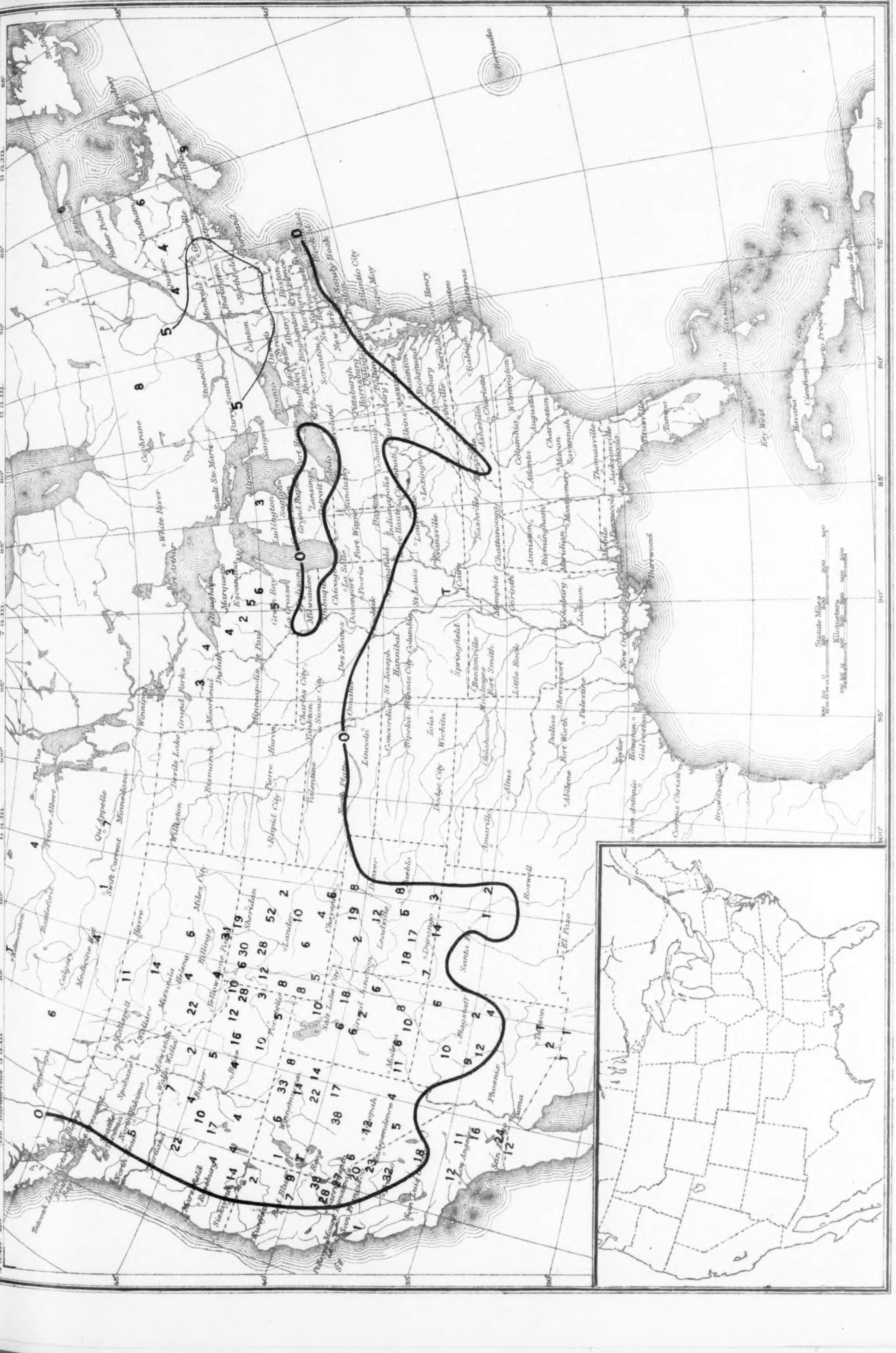

Chart VIII. Weather Map of North Atlantic Ocean, April 6, 1925

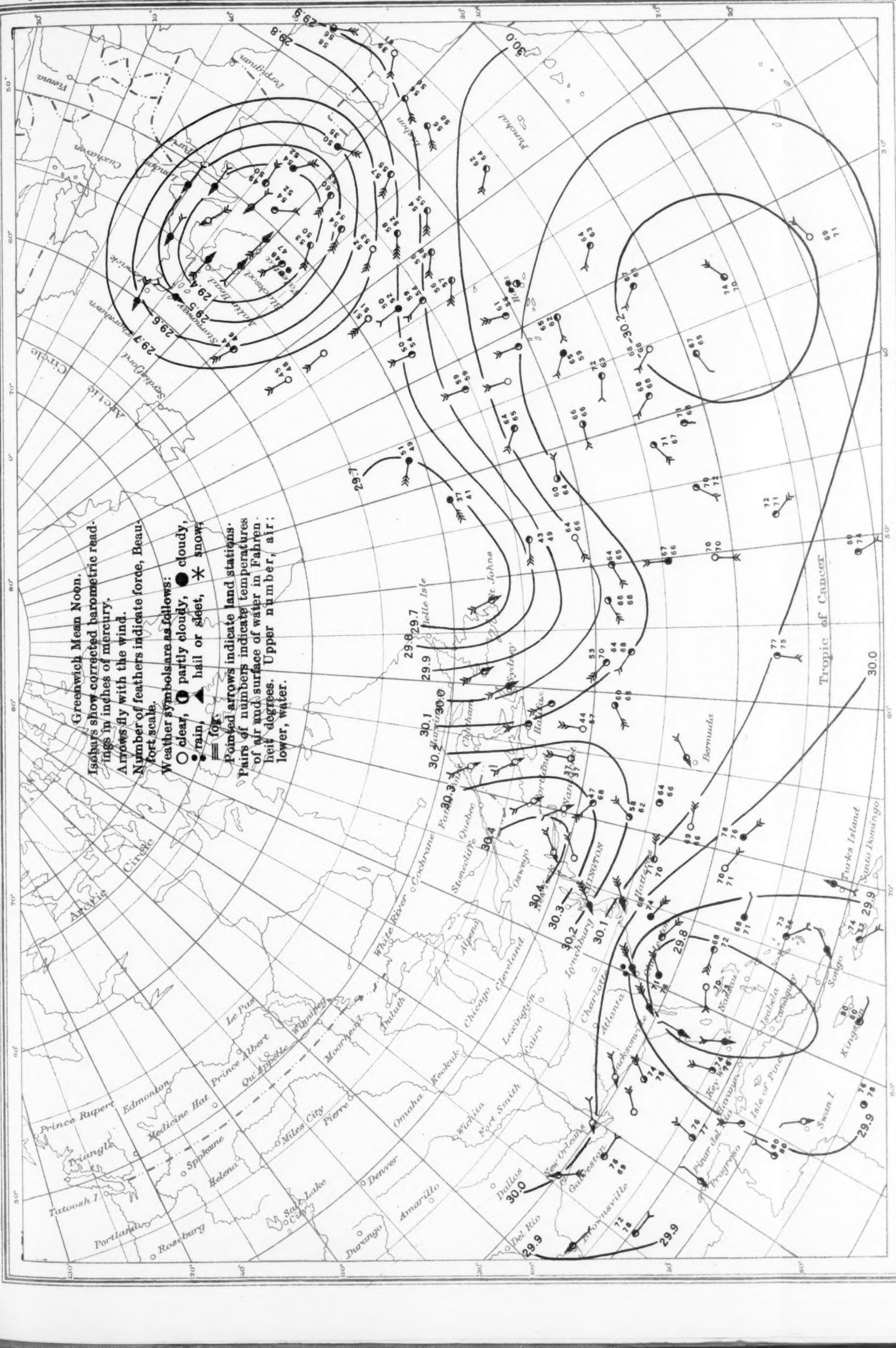

Chart IX. Weather Map of North Atlantic Ocean, April 7, 1925

(Plotted by F. A. Young)

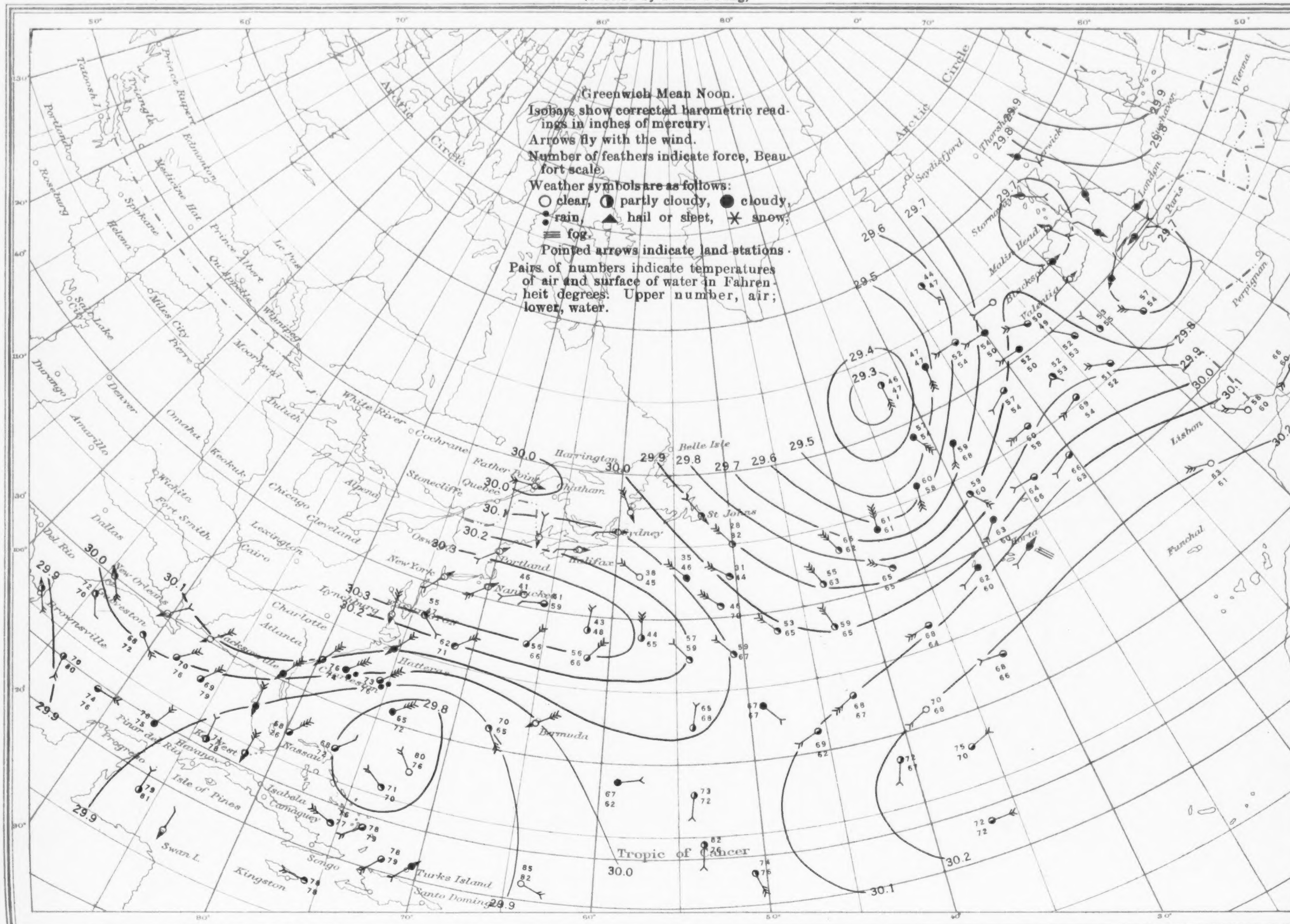

Chart X. Weather Map of North Atlantic Ocean, April 8, 1925

(Plotted by F. A. Young)

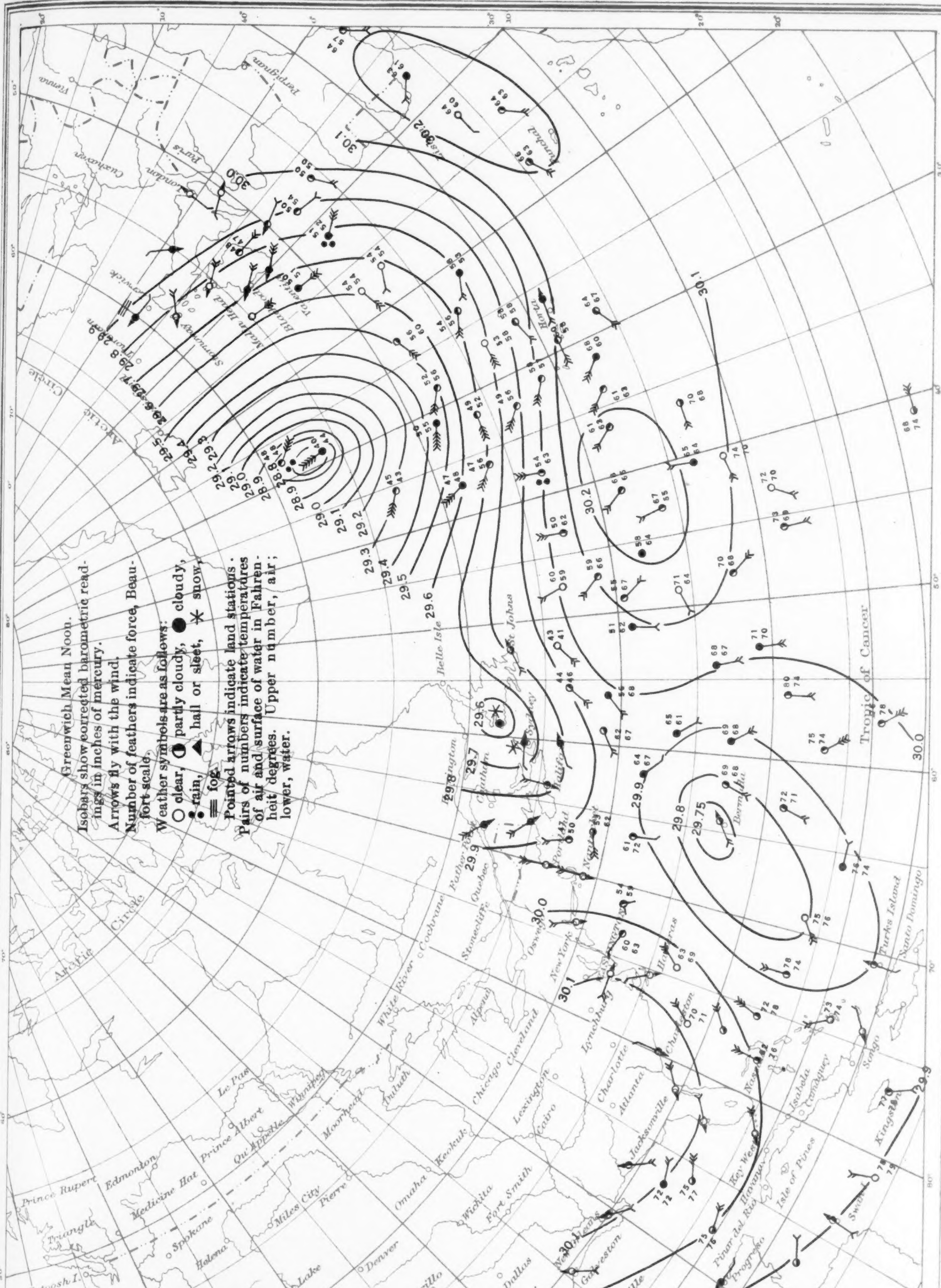

Chart XI. Weather Map of North Atlantic Ocean, April 9, 1925

(Plotted by F. A. Young)

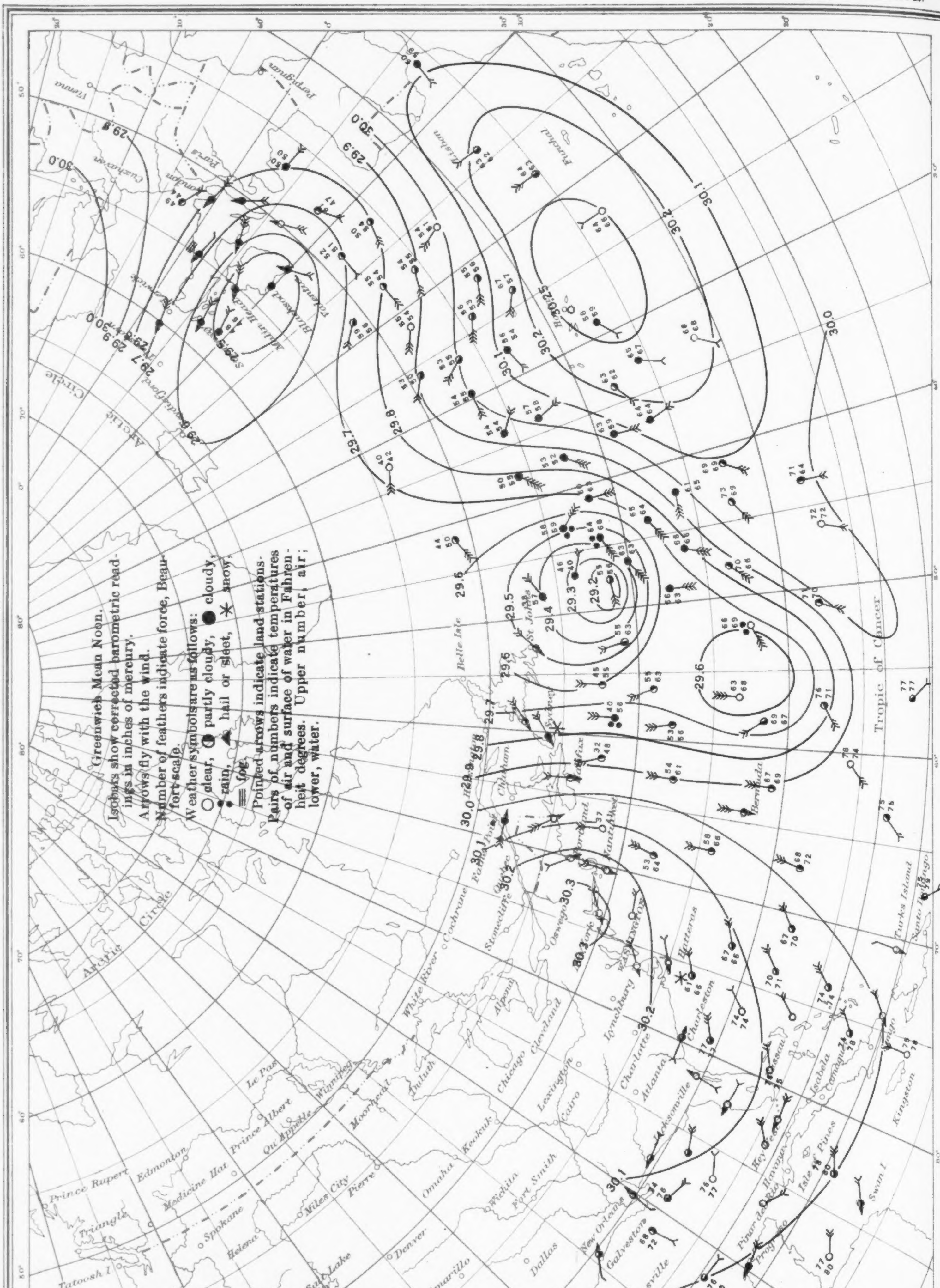

Chart XII. Weather Map of North Atlantic Ocean, April 10, 1925
(Plotted by F. A. Young)

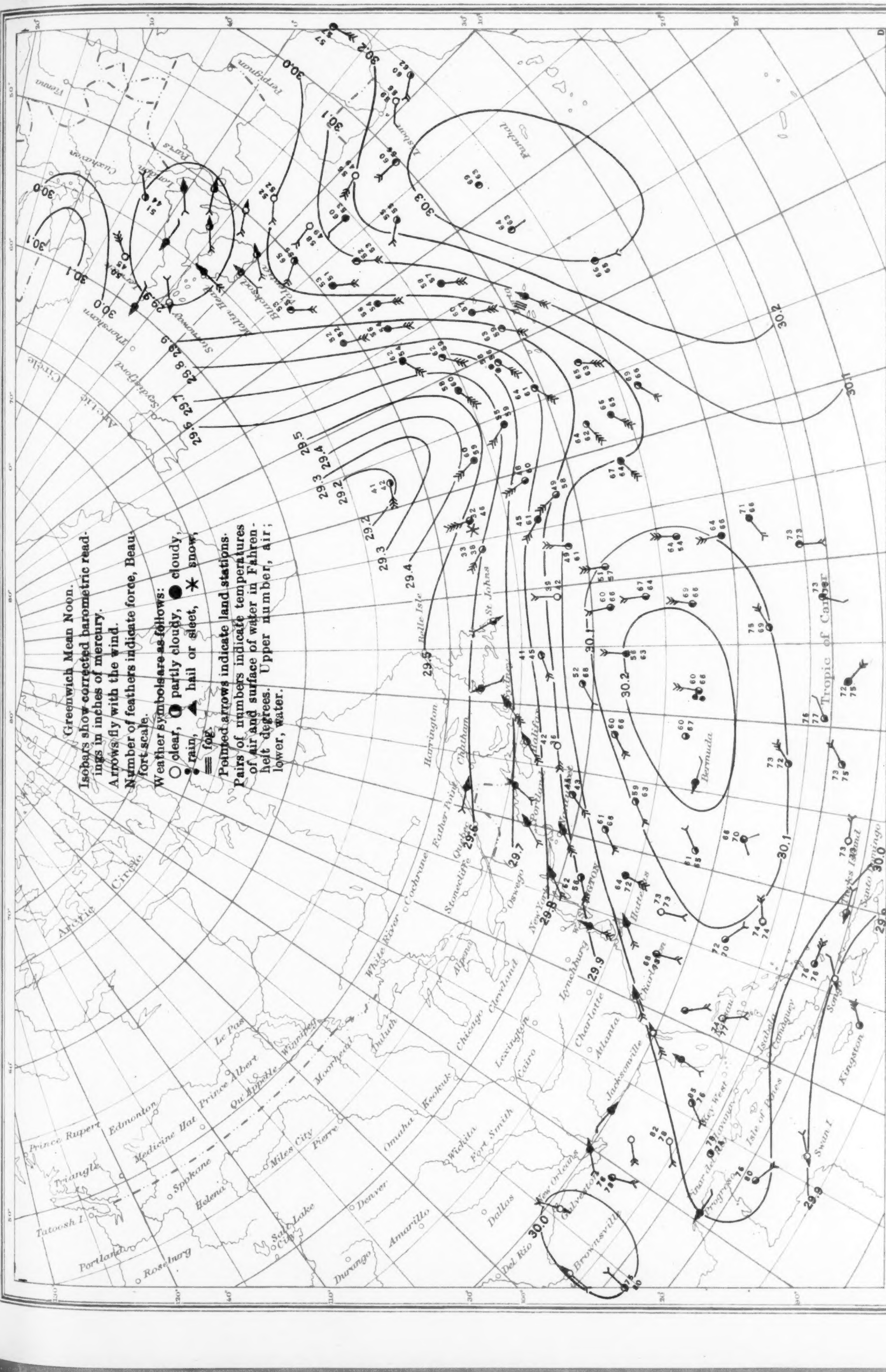

Chart XIII. Weather Map of North Atlantic Ocean, April 11, 1925

(Plotted by F. A. Young)